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**POTENTIAL HUMAN EXPOSURES
FROM LEAD IN
MUNICIPAL: SOLID WASTE**

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In the past **20** years, environmental policymakers have focused a great deal of attention on the health risks associated with the production, use, and disposal of lead and lead-bearing consumer products. Lead exposure has been linked to a variety of acute and chronic health effects. Early regulatory initiatives limited lead exposures by restricting the **use** of lead in gasoline and housepaint. In addition, use of lead solder in food cans has been dramatically reduced. While these measures have significantly reduced lead exposures in the general population, **EPA** is currently considering additional regulatory strategies, including restricting **uses** of lead in consumer products. Additionally, the U.S. Congress and state legislatures are considering (and in some cases have approved) legislation that would restrict lead in packaging. These approaches appear to be motivated in part by a concern that disposal of lead-bearing products in municipal solid waste (MSW) could result in adverse human exposures to lead.

The purpose of this report is to review available information on whether the disposal of lead-bearing products in the municipal waste stream poses a significant threat to public health. The report is based primarily on published information sources, supplemented by conversations with state officials and researchers working on the environmental fate of lead. The goal is to provide the reader with a detailed summary of the information and data on the potential for lead in MSW to be released to the environment at levels that would cause adverse human exposures.

The report focuses on the potential exposures caused by landfilling of unprocessed MSW and waste incineration, the two dominant refuse disposal practices in the U.S. Prior to this discussion of exposures, however, **Chapter 2** provides some general background information on the sources and quantities of lead in the municipal waste stream. This information is included to give the reader an overview of the types of lead-bearing consumer products in MSW and the quantities of lead they contribute to the waste stream. The reader should note, however, that quantity information alone tells **us** nothing about the likelihood that MSW disposal poses a threat to public health. For this reason, the most valuable information in the report **is in** the following two chapters, which address potential exposures.

Chapter 3 focuses on the possible exposures resulting from disposal of unprocessed MSW in landfills. In this case, the potential for lead to leach from landfills and contaminate underground drinking water supplies **is** identified as the primary exposure pathway of concern. To evaluate the likelihood of such contamination, we analyzed data on the leachability of lead from MSW and the behavior of lead once it is released from a landfill to the groundwater. In addition, **we** reviewed

information on reported incidents of lead contamination that might be linked to disposal of municipal solid waste to see if there have been any incidents where disposal of lead-bearing MSW is known to have contaminated drinking water supplies. Finally, we analyzed state monitoring databases to assess the degree to which lead from MSW landfills is present in surrounding groundwater.

For the Chapter 4 analysis of potential exposures due to incineration of municipal solid waste, we considered a variety of potential exposure pathways. First, we evaluated data on the ambient air concentrations around municipal waste combustors (MWCs) in the U.S. and compared these levels to the National Ambient Air Quality Standard (NAAQS) for lead. We conducted a similar review of fugitive emissions both around MWCs and at ash disposal facilities. The analyses considered both direct inhalation exposures, as well as indirect exposures that might result from ingestion of contaminated soil or dust. We also reviewed information on the leachability of lead from incinerator ash, and on the likelihood that leachate releases could result in lead concentrations above the drinking water action level (0.015 mg/l) at wells located near ash disposal sites.

Based on the results of the landfill and incinerator analyses, we conclude that lead in municipal solid waste does not pose a significant threat to public health, and as a result concerns about MSW should not be used as a basis for restricting uses of lead in consumer products that ultimately end up in the waste stream. The basis for this conclusion is summarized in the following observations about the likelihood that MSW lead causes adverse exposures.

- o Analysis of the fate and transport of lead in municipal landfill leachate suggests a very low likelihood that nearby drinking water wells would ever contain lead concentrations in excess of the recently announced drinking water action level (0.015 mg/l). For virtually all of the leachate samples analyzed, dilution and attenuation processes occurring during groundwater transport ensure that the action level standards will not be violated.¹ For example, most leachates (86 percent of the samples analyzed) would require less than a 10-fold reduction in concentration, which is highly likely for most sites in the U.S. Actual dilution/attenuation factors for lead are probably much higher at most locations in the country. Applying the dilution/attenuation factor established for lead by EPA's Toxicity Characteristic regulation, over 99 percent of the leachate samples analyzed would be reduced to below the current drinking water action level.
- o Recent experience at municipal landfills confirms that releases of lead-bearing leachate are unlikely to pose problems. Conversations with state regulators and a review of 146 municipal landfills reporting contamination problems (not necessarily due to lead) revealed only two facilities where off-site migration of lead may have contaminated drinking water wells; in both these cases the contamination is believed to have been caused by co-disposal of large quantities of hazardous industrial waste along with municipal refuse, a practice

¹Dilution occurs as the leachate is dispersed into a larger volume of groundwater. Attenuation is a measure of the extent to which the lead is retained in the subsurface soil either through precipitation or through adsorption onto soil particles.

no longer allowed by federal regulations. A review of additional groundwater monitoring data for five states also points to the low likelihood of off-site exposures to elevated lead levels around **MSW** landfills.

- o Overall, landfills appear to be effective long-term sinks for lead. Our calculations show that for a typical landfill less than 0.001 percent of the lead in the municipal waste is expected to leach out in any given year. As a result, even after 10,000 years of leaching, in excess of 95 percent of the lead originally placed in the facility is still there.

For municipal waste combustors the likelihood of any adverse exposures due to lead in the waste also appears slight.

- o For stack emissions, EPA's own studies suggest that ambient air concentrations of lead in the worst case scenarios will be at levels that are less than five percent of the current lead NAAQS.
- o Based on available data, fugitive emissions from incinerator ash handling and disposal practices also are not a major cause for concern. EPA's modeling analysis, which makes very conservative assumptions about the levels at which adverse exposures occur, indicates that such exposures would be expected on-site less than five percent of the time. Off-site, no adverse exposures are predicted. These results are confirmed by industry monitoring studies which found that air concentrations of fugitives can be maintained at close to background levels.
- o Analysis of ash monofill leachate data suggests that dilution and attenuation processes occurring during groundwater transport ensure that lead concentrations at nearby water supply wells are unlikely to exceed the drinking water action level.
- o Furthermore, air monitoring data around an ash monofill indicate that lead is not building up in the soil due to air deposition from disposal operations. This lends further support to the conclusion that long-term buildup of lead in the environment is not occurring as a result of waste combustion practices.

In summary, the extremely limited potential for exposure suggested by this multi-pathway review indicates that concerns about lead in **MSW** may be unwarranted. Management of **MSW** in landfills and incinerators effectively controls releases of lead in both the near- and long-term, eliminating the need for EPA, congressional, or state initiatives based on concerns about **MSW**. The remaining chapters of this report provide a more detailed discussion of the basis for these conclusions.

INTRODUCTION

This chapter reviews available information **on** the quantity of lead in municipal solid waste (MSW). Three specific questions are addressed:

- o What is the total quantity of lead entering the municipal solid waste stream each year?
- o What products contribute lead to the waste stream and in what proportions?
- o How is this lead distributed between landfills and incinerators, the two primary MSW disposal methods?

The answers to these questions provide general background information **on** the presence of lead in MSW. The reader should note, however, that the mere presence of lead in the waste stream does not imply the existence of adverse human **exposures**. The answer to the question of whether lead in MSW is the source of unacceptable **exposures** is addressed explicitly in Chapters 3 and 4.

TOTAL LEAD IN MSW

The ideal approach for determining the quantity **of** lead in **MSW** would be a systematic nationwide sampling of the lead content of municipal refuse. Unfortunately **no** one has ever conducted such a study. **As** a result the total quantity of lead in MSW must be inferred from other **types** of data. **In** this section we present the results of three alternative approaches for estimating the amount of lead in MSW.

1. EPA's materials flow approach in which the amount of lead entering MSW is based **on** lead consumption in various consumer products.
2. **An** ash sampling approach in which concentrations of lead in municipal waste combustor (MWC) ash are combined with estimates of national MSW generation to infer total lead in MSW.

3. A sampling approach in which some very limited information on the measured lead content of MSW itself is used to determine total lead in MSW nationally.

The data presented in this chapter suggest that estimates of lead in MSW are sensitive to both the approach selected and to the assumptions made about recycling and disposal of lead-acid batteries. As a result the three methods yield significantly different estimates of the amount of lead in MSW, with EPA's own materials flow estimates at the upper end of the range.

Materials Flow Estimates of Lead in MSW

The materials flow method for estimating the amount of lead in MSW was employed by Franklin Associates, Ltd. in the 1989 report Characterization of Products Containing Lead and Cadmium in Municipal Solid Waste in the United States, 1979 to 2000. For each lead-containing product that may end up in the municipal solid waste stream, Franklin collected historical data on the amount of lead consumed in the production of these products. Data from the U.S. Bureau of Mines served as the primary starting point for these estimates. Franklin then subtracted out lead that is lost in the manufacture of the product, and adjusted for foreign trade (subtracting exports and adding imports). Finally, they projected the amount of time it takes for the lead to reach the waste stream by estimating the lifetime of the product and assuming that the product will be discarded at the end of this period. These estimates of gross discards were adjusted for materials recovery (recycling), and the remaining portion was Franklin's estimate of net discards of lead in MSW.

Using the 1986 figures from Franklin's study, total gross discards of lead from all products were estimated to be **776,404** tons. The vast majority of these discards (over 700,000 tons) were attributable to lead-acid (SLI) batteries. From the total gross discards, Franklin estimated that secondary smelters recovered approximately 73 percent of the lead. Most of this comes from lead-acid batteries, for which Franklin assumed an 80 percent recycling rate. This recycling assumption is central to the estimate of lead in MSW and will be discussed further below. After recovery, Franklin projected net discards of lead to be **213,653** tons per year.

The large proportion of lead-acid batteries in gross lead discards (roughly 90 percent) implies that Franklin's estimates of lead entering the municipal solid waste stream are very sensitive to the assumed battery recycling rate. Franklin projected gross discards of lead in SLI lead-acid batteries to be **700,610** tons, with **562,614** tons recycled -- a recovery rate of **80.3** percent.¹ This estimate was developed by projecting data on lead used in battery production forward by four years (the average battery life) and treating this as the total gross discards of battery lead in that year. The recycling rate was obtained by dividing Bureau of Mines data on total lead recovered from battery scrap by the gross discards estimate.

¹Franklin, 1989, Table 2-21, page 81.

Lead industry experts believe Franklin's **1989** study significantly understated the recycling rate for lead-acid batteries, and that a recycling rate of at least **90 percent** is more appropriate! A recent Battery Council International (BCI) estimate suggests the rate may be above **95 percent**. In the **1990** update to their more general survey of MSW quantities, Franklin adopted a **90 percent** rate themselves.' Applying this higher rate to the earlier Franklin estimate of gross discards implies the recovery of **630,549** tons of lead. At this recycling rate only **70,061** tons of battery lead enter the waste stream. Assuming all unrecycled batteries are disposed in municipal refuse implies MSW lead of **145,718** tons, as opposed to **213,653** tons originally estimated by Franklin.

In summary, the materials flow method estimates net discards of lead to be between **145,718** tons and **213,653** tons, with the range attributable to the assumed rate of battery recycling. The lower end of the range probably provides the more accurate estimate given the recent agreement among Franklin and industry experts that a recycling rate of at least **90 percent** is appropriate. Therefore, this chapter uses the estimate of **145,718** tons as the baseline of comparison for other estimates of lead in MSW.

Even **145,718** tons may be an overestimate, however, given the results of a recent survey by the Battery Council International (BCI).⁴ Based on approximately **1,000** telephone interview., the BCI study found that **19 percent** of all **U.S.** households were storing old automotive batteries. This suggests that Franklin's assumption that any battery not recycled will end up in the municipal waste stream almost certainly overstates the number of batteries actually disposed of at landfills and combustors.

Using Ash Samples to Estimate Lead in MSW

An alternative to the materials flow method of estimating lead present in MSW uses sampled concentrations of lead in MWC residues to infer the amount of lead in the incoming refuse. These estimates can then be scaled to arrive at an estimate of the lead in MSW nationally. Although the range of quantities projected is wide, this method consistently yields estimates of lead in MSW that are less than those found using the materials flow method.

⁴Personal communication with Dave Cook of Lake Engineering, Inc., August **1989**.

³Franklin Associates, Ltd., Characterization of Municipal Solid Waste in the United States: 1990 Update, prepared for U.S. EPA June **1990**, page **17**.

²Peter D. Hart Associates, Inc., "Findings from a Survey Conducted for the Battery Council International" April **1990**.

The estimates for this approach were developed based on concentrations of lead in **59** ash samples.' Two types of ash samples were available. In divided ash samples, lead concentrations are given for bottom ash and fly ash; these were weighted by the amount of each type of ash per ton of MSW burned to get an overall estimate of the lead concentration in the incoming MSW.⁶ In combined ash samples, a combination of fly and bottom ash was tested for lead content. Combined ash concentrations were weighted by the total amount of lead per ton of MSW burned to infer the concentration in the as-fired MSW.' This ash yield varies according to the type of incinerator in question, and by a variety of parameters that control the efficiency of the combustion process. In general, incinerators are estimated to generate between 0.15 and **0.35** tons of ash per ton of MSW burned (i.e., a weight reduction efficiency of between **65** and **85** percent)!

Exhibit 2-1 presents both mean and median concentrations derived from the distribution of **59** ash samples. The dependence of these mean and median concentrations on the incineration efficiency is reflected in this table, with the implied MSW lead concentration being lower when the burn efficiency is higher.' The mean lead concentration in MSW suggested by the ash samples is between **536** ppm and **895** ppm. Multiplying by the total annual estimate of MSW generation (**156** million tons?), ye-estimate that between **83,616** and **139.620** tons of lead enter the waste stream annually. This estimate is between **4** and **43** percent lower than that obtained by the materials flow method with 90 percent battery recovery.

'Ash samples were taken from the following reports: (1) Characterization of MWC Ashes and Leachates from MSW Landfills, Monofills, and Co-Disposal Sites: Characterization of Municipal Waste Combustor Residues. NUS Corporation, prepared for U.S. EPA, October, **1987**; (2) Characterization of Municipal Waste Combustor Ash, Ash Extracts, and Leachates, NUS Corporation, prepared for Coalition on Resource Recovery and U.S. EPA, March, **1990**; and (3) National Incinerator Testine and Evaluation Proeram: The Characterization of Mass Burning Incinerator Technology, Vol. IV. Lavalin. Inc., prepared for Conservation and Protection Environment Canada, **1987**.

⁶Estimates of the amount of each type of ash produced per ton of MSW burned were given in the reports from which these figures are taken.

For example, if the concentration of lead in the ash sample is **1,000** ppm and **0.25** tons of ash are generated per ton of MSW burned, the concentration of lead in the incoming MSW is **1000 x (0.25) = 250** ppm.

⁸Facing America's Trash: What's Next for Municipal Solid Waste? Office of Technology Assessment, October, **1989** Special Manaeement Standards for Municipal Waste Combustor Ash, Midwest Research Institute, prepared for U.S. EPA, Municipal Solid Waste Program, June, **1990**.

⁹Franklin Associates, Ltd.. **1990**, page **55**; estimate is post-recycling generation for **1988**; we are assuming that comparing lead estimates using this figure to **1986** Franklin materials flow figures does not introduce significant inconsistencies.

Exhibit 2-1

ESTIMATING LEAD IN MSW USING
LEAD CONCENTRATIONS IN INCINERATOR ASH

Using Median Ash Concentration			
Tons of Ash Per Ton of MSW Burned	Median Implied MSW Lead Concentration (ppm)	Implied Lead in MSW (tons)	Percentage Difference from Franklin (90% Battery Recovery)
0.15	357	55,692	61.8%
0.25	455	70,980	51.3%
0.35	595	92,820	36.3%

Using Mean Ash Concentration			
Tons of Ash Per Ton of MSW Burned	Mean Implied MSW Lead Concentration (ppm)	Implied Lead in MSW (tons)	Percentage Difference from Franklin (90% Battery Recovery)
0.15	536	83,616	42.6%
0.25	716	111,696	23.3%
0.35	895	139,620	4.2%

Number of Samples = 59

Source: IEc analysis of

(1) NUS Corporation, "characterization of MWC Ashes and Leachates from MSW Landfills, Monofills, and Co-Disposal Sites: Characterization of Municipal Waste Combuster Residues", prepared for U.S. EPA, October, 1987.

(2) NUS Corporation, "Characterization of Municipal Waste Combuster Ash, Ash Extracts and Leachates", prepared for Coalition on Resource Recovery and U.S. EPA, March, 1990.

(3) Lavalin, Inc., "National Incinerator Testing and Evaluation Program: The Characterization of Mass Burning Incinerator Technology", prepared for Conservation and Protection Environment Canada, Vol. IV, 1987.

Estimates based on the median ash concentration suggest a lower MSW lead quantity of between **55,692** tons and **92,820** tons (between **36** and **62** percent lower than the materials flow estimates). Because several exceptionally high ash concentrations of lead (i.e., over 5000 ppm) skew the mean MSW lead concentration, the median probably provides a more reasonable estimate of the typical waste lead content.

Overall we believe the best ash-derived estimate of MSW lead is one based on the median ash concentration and assuming **25** tons of ash per **100** tons of waste. This midpoint burn efficiency suggests an MSW lead concentration of **455** ppm and implies an annual total of roughly **71,000** tons of lead in the waste stream, approximately half of the amount suggested by the materials flow method with 90 percent battery recovery. These findings, based on actual ash samples, suggest that the materials flow method systematically overstates the amount of lead in MSW if the waste burned at incinerators has a lead content similar to MSW disposed of in landfills. This is a reasonable assumption since the ash samples are representative of mass burn incinerators that perform minimal pre-sorting of their waste.

Sampling Estimates of Lead at MWCs

A third method of estimating lead in MSW is to examine actual concentrations of lead found in municipal refuse samples and to scale these concentrations to the overall waste stream. Exhibit 2-2 reviews the **results** of five studies that included direct analysis of the lead content of MSW.¹⁰ These studies provide some information on MSW lead content, although the amount of garbage sampled in any one study was small. In these samples, concentrations range from **19** to **1771** parts per million (ppm) with an average of **319** ppm. Applying the average of these concentrations to the total MSW generated in the U.S. (**156** million tons) yields an estimate of **49,764** tons of lead entering the municipal solid waste stream. This is 66 percent lower than the Franklin estimate incorporating the **90** percent battery recovery rate. If we apply the median lead concentration (148 ppm), we estimate that **23,088** tons of lead enter the waste stream annually."

¹⁰The figures in Exhibit 2 come from incinerators that performed MSW analyses for various trials. It should be noted that the **Buekens**, NITEP, and van de Beek studies used MSW from Germany, Canada; and the Netherlands respectively. There may be uncertainty in estimates based on these figures if the lead content of MSW in these countries differs from that in the U.S.

¹¹The concentrations of lead found using MSW sampling are **significantly** lower than those inferred from ash samples. Two factors may account for this discrepancy: (1) In the testing laboratories, MSW is generally processed in a grinder and a sample of ground-up waste is drawn and analyzed; it is possible that many of the products in which lead occurs most frequently (batteries, TVs) may not be suitable for such grinding and may be diverted before sampling; and/or (2) the distribution of lead in the waste stream may be so heterogeneous that our sample of **23** MSW concentrations was not statistically sufficient, i.e., we did not capture any of the high concentrations that **occasionally occur** in MSW as evidenced by the ash samples discussed above.

Estimated Lead in MSW Using Sampling Method		
Study Reviewed	Reported Average Lead Concentration in as-Received MSW Samples (ppm)	Estimated Lead in MSW' (tons)
Boughton, 1989	36	5,688
	19	3,049
	88	13,920
	349	55,142
Buekens, 1989	678	107,124
Sommer, et al., 1988	135	21,330
	148	23,384
	166	26,228
NITEP, 1988	144	22,464
	125	19,500
	205	31,980
	1,321	206,076
	159	24,804
	56	8,736
	193	30,108
	200	31,200
	135	21,060
	99	15,444
	1,771	276,276
	90	14,040
	640	99,840
	121	18,876
van de Beek, 1988	450	70,200
AVERAGE	319	49,764
MEDIAN	148	23,088

- * Calculated by multiplying ppm lead estimate by overall MSW volume of 156 million tons.

Sources:

- (1) Boughton, Robert and Gildart, Martha, "Coordinated Waste, Ash, and Emissions Sampling at the Commerce Refuse-to-Energy Facility". California Integrated Waste Management Board, 1989.
- (2) Buekens, A.G.. "Refuse Incineration in Europe". in Proceedings to International Conference on Municipal Waste Combustion, Vol.1, 1989.
- (3) Sommer, Ed J., "Emissions, Heavy Metals, Boiler Efficiency, and Disposal Capacity for Mass Burn Incineration with a Presorted MSW Fuel", National Recovery Technologies, Inc., 1988.
- (4) Lavolin, Inc., "National Incinerator Testing and Evaluation Program: The Characterization of Mass Burning Incinerator Technology", prepared for Conservation and Protection Environment Canada; Vol.IV, 1987.
- (5) van de Beek, A.I.M. et al., "Fysisch en Chemisch Onderzoek aan Huishoudelijk Afval", June, 1988.

Other evidence from actual MSW samples also indicates a potential tendency for the materials flow method to overstate the amount of lead entering the waste stream. In a study conducted by the Garbage Project, 66 tons of MSW were hand-sorted for significant lead-bearing items such as lead-acid batteries and television sets. Two batteries were found, contributing an estimated 40 pounds of lead.¹ The Franklin estimates of battery lead in MSW suggest 0.0009 tons of battery lead per ton of MSW, implying that a 66 ton sample would contain 116 pounds of battery lead, or roughly six batteries. This is three times the number actually found in the Garbage Project MSW sample. Furthermore, the sample found no televisions, the source Franklin estimates as contributing 24 percent of the lead in MSW (the second largest contributor).

PRODUCTS CONTRIBUTING LEAD TO MSW

Franklin's materials flow study provides the only available estimates of the proportion of MSW lead contributed by individual consumer products. According to Franklin, batteries are the single largest contributor of lead to the waste stream. However, as with the overall quantity of lead disposed, the relative proportion contributed by various items depends heavily on the assumed rate of battery recycling. Exhibit 2-3 shows that if a battery recycling rate of 80 percent is assumed, batteries make up about 65 percent of net discards; if we assume the 90 percent recycling rate, this figure falls to 48 percent and other contributors become more significant. Exhibit 2-4 presents a more detailed description of Franklin's estimates of the relative contribution of various lead-bearing products assuming the 90 percent battery recycling rate.

While the Franklin study does provide estimates of individual product contributions, these should be viewed as only very rough indicators because of the uncertainties inherent in the materials flow methodology. As noted previously, the Franklin approach has never been validated through extensive sampling of municipal refuse. Furthermore available evidence on the lead content of incinerator ash suggests that the materials flow method may significantly overstate the lead content of MSW. Such an overstatement implies that some of the individual product contributions also contain substantial inaccuracies.² Due to these uncertainties we conclude at present that available data provide only sketchy information on the relative contribution of lead-bearing consumer products to total MSW lead.

DESTINATION OF LEAD-BEARING MSW

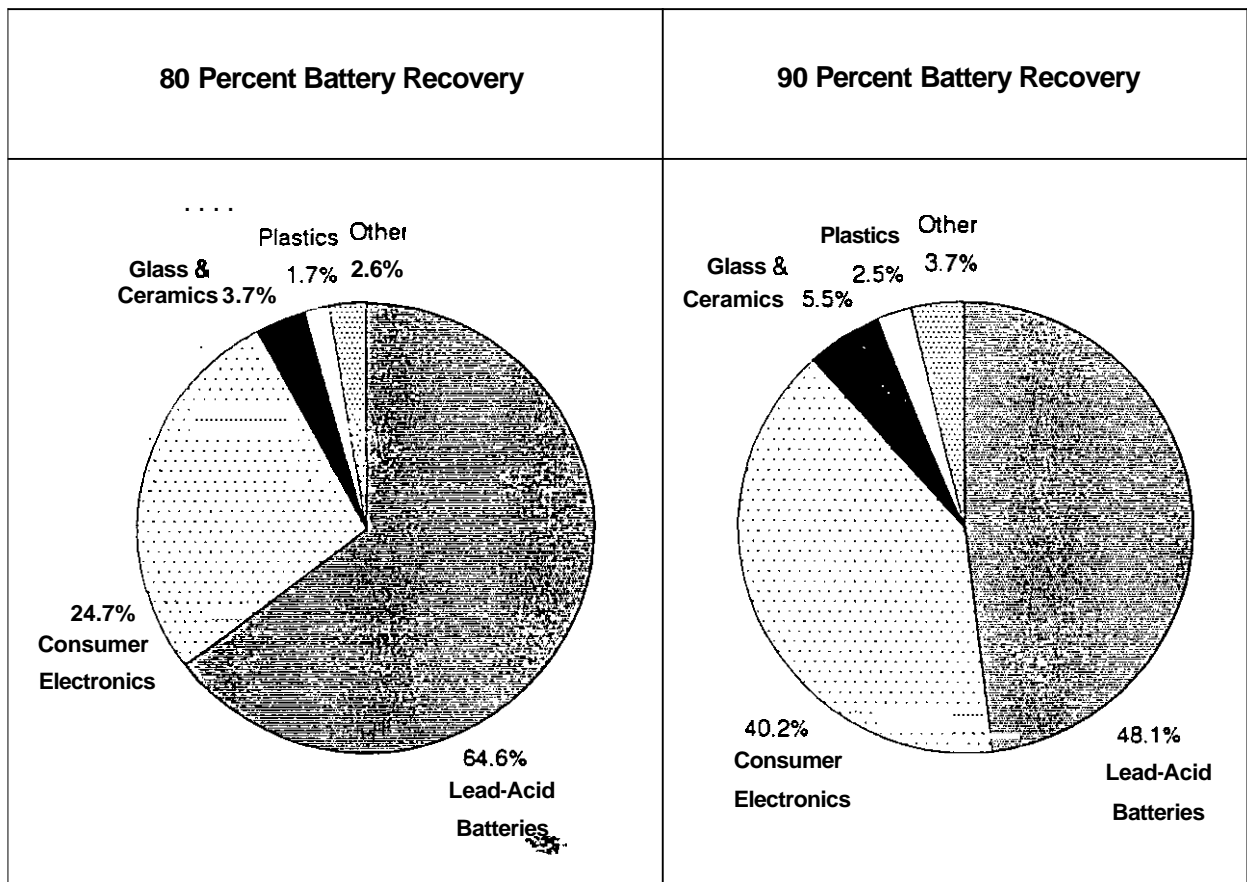
Under current management practices, MSW is either buried in Subtitle D landfills or sent to MWO for incineration. At present EPA estimates that 16 percent of MSW is sent to MWCs, with the remaining 84 percent going to municipal solid waste landfills (MSW landfills).³ Assuming that these general MSW figures apply to lead-bearing products, Exhibit 2-5 summarizes the various estimates of lead in MSW and partitions the estimated amounts between MSW landfills and MWCs. Taking the materials flow method with 90 percent battery recovery as an upper-bound, approximately

¹"Wilson, Douglas. "Lead Archaeology Methods to Quantify Lead In Modern Residential Refuse," The Garbage Project, University of Arizona, prepared for Lead Industries Annual Meeting, May 11, 1989.

²Franklin Associates, Ltd., 1990.

Exhibit 2-3

CONTRIBUTORS TO LEAD IN MSW UNDER 80 PERCENT VERSUS 90 PERCENT RECOVERY OF LEAD-ACID BATTERIES



Source: IEC analysis of Franklin, 1989.

4.

Exhibit 2-4
(continued)

DISCARDS* OF LEAD IN PRODUCTS IN THE MUNICIPAL WASTE STREAM, 1986 RANKED IN ORDER OF WEIGHT OF LEAD: 90 PERCENT BATTERY RECOVERY (in short tons and percent of total)			
Products	Lead in MSW	Lead at MWCs	Percent
PIGMENTS++			
Printing inks	265	43	0.2%
All other products	866	142	0.6%
Subtotal - pigments	1,131	185	0.8%
LIGHT+ BULBS			
Glass	709	116	0.5%
Solder	225	37	0.2%
Subtotal - light bulbs	934	153	0.6%
COLLAPSIBLE TUBES	639	104	0.4%
BRASS AND BRONZE PRODUCTS	321	52	0.2%
FOIL WINE WRAPPERS	202	33	0.1%
USED OIL	192	31	0.1%
RUBBER PRODUCTS			
Tires and tire products	48	8	0.03%
All other rubber products	21	3	0.01%
Subtotal - rubber products	69	11	0.05%
GRAND TOTAL	145,718	23.825	100.0%

* Discards after recycling.

** Except for glass in light bulbs and television sets.

+ Except for plastics in consumer electronics.

++ Except for pigments in glass, plastics, and rubber.

Sources: (1) IEC analysis of Franklin Associates, Ltd., "Characterization of Products Containing Lead and Cadmium in Municipal Solid Waste, 1970 to 2000", prepared for U.S. EPA. January, 1989.

(2) IEC analysis of Franklin Associates, Ltd., "Characterization of Municipal Solid Waste in the United States: 1990 Update", 1990.

SUMMARY OF LEAD IN MSW ESTIMATES AND AMOUNTS SENT TO LANDFILLS AND INCINERATORS			
Estimation Method	Estimated Annual Net Discards of Lead (tons)	Amount Sent to MSWLFs (tons)	Amount Sent to MWCs (tons)
1. Materials flow			
- 80% battery recovery	213,653	178,721	34,932
- 90% battery recovery	145,718	121,893	23,825
2. Ash sampling			
- Mean (0.25 ash yield)	111,696	93,434	18,262
- Median (0.25 ash yield)	70,980	59,375	11,605
3. MSW sampling			
- Mean	49,764	41,628	8,136
- Median	23,088	19,313	3,775

Sources:

- (1) Franklin Associates, Ltd., "Characterization of Products Containing Lead and Cadmium in Municipal Solid Waste, 1970 to 2000", prepared for U.S. EPA, January, 1989.
- (2) Franklin Associates, Ltd., "Characterization of Municipal Solid Waste in the United States: 1990 Update", 1990.
- (3) IEC analysis.

122,000 tons of lead are sent to MSW landfills annually, while 24,000 tons are disposed of at MWCs. Estimates for landfills and incinerators based on the ash analysis or refuse sampling approaches would be significantly lower due to their lower predictions of annual net discards.

The estimates presented probably overstate the total lead at municipal combustors because they fail to account for pre-sorting of wastes at a substantial fraction of the facilities. According to Franklin, 98 percent of all lead is contained in non-combustible products, a portion of which is almost certainly removed from wastes at municipal combustors and diverted to landfills.” Assuming this separation is employed primarily at refuse-derived fuel (RDF) incinerators which account for 23 percent of the existing MWC capacity, approximately 5,400 tons of lead would be diverted to landfills (using the Franklin estimate with 90 percent battery recovery as discussed above). This constitutes a 22.5 percent decrease in lead sent to MWCs, and a 4.4 percent increase in the amount sent to municipal solid waste landfills. As a result, lead actually combusted in MSW would fall from 24,000 to 18,000 tons.

Regardless of the amount of lead incinerated at municipal combustors, it is worth noting that landfills are the ultimate repository for virtually all the lead in municipal solid waste. This occurs because upwards of 98 percent of the lead in combusted MSW remains in the ash.¹³ This ash is almost always either co-disposed in landfills with unprocessed municipal waste or placed in ash monofills. For this reason, precise estimates of the amount of lead burned at MWCs are not particularly important.

CONCLUSIONS

The data presented in this chapter suggest there is still considerable uncertainty about the quantity of lead entering the municipal waste stream. At the upper end of the range are EPAs materials flow estimates suggesting that approximately 146,000 tons of lead enter the municipal waste stream annually. Estimates using concentrations of lead in ash suggest that the materials flow method overstates lead discards, and that the amount of lead entering the waste stream is more likely between 71,000 and 111,700 tons. Actual sampling of MSW suggests even lower discards of between 23,000 and 50,000 tons per year, the bottom of the range being almost a full order of magnitude below the materials flow estimate.

Considerable uncertainty also is present in the estimates of the contributions of individual products to the total quantity of lead in MSW. The materials flow estimates suggest batteries account for more lead than any other product in the waste stream, although these estimates have never been validated through field sampling of municipal refuse. Given the potential for error in the materials flow method, the estimates of individual product contributions may not provide very accurate indicators of the actual quantity of lead attributable to a particular class of consumer products.

¹³Franklin Associates, Ltd., 1989, page 31.

¹⁴See discussion in Chapter 4.

Given the potential inaccuracies in both the estimates of total lead in MSW and individual product contributions, any future **EPA** regulatory analyses involving MSW lead should explicitly incorporate these uncertainties into assessments of the costs and benefits of additional regulation. Regulatory analyses that rely solely on the materials **flow** estimates will not adequately represent the range of possible outcomes.

Finally, we would like to emphasize again that while lead is certainly present at relatively low concentrations in MSW, its presence alone is not a demonstration that MSW lead causes any environmental or public health problems. Of much greater importance is whether the lead is **released** to the environment at concentrations that result in adverse exposures. This is the topic of the next two chapters.

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INTRODUCTION

Disposal of lead-bearing municipal waste in landfills only has the potential to cause adverse effects if the lead is released to the environment and results in human **exposures** to lead concentrations that exceed applicable EPA standards. In the disposal of unprocessed municipal solid waste in landfills, groundwater is the principal exposure pathway of concern. Placement of lead-bearing consumer products and waste in such facilities can result in the presence of lead in the landfill leachate although the contribution of lead by individual products and wastes is unknown.¹ If this leachate is released to a potable aquifer, the lead potentially could be transported to drinking water wells adjacent to the facility.

This chapter examines the potential for such leachate releases to cause **exposures** to lead in groundwater at levels above **EPA's** recently announced drinking water action level (0.015 mg/l).² We consider both the short- and long-term performance of municipal solid waste landfills in containing lead releases. The chapter is divided into two primary sections. The first reviews available information on the likelihood that lead **levels** around MSW landfills would ever exceed the drinking water action level for lead. This discussion includes a review of the available data on lead concentrations in landfill leachate; estimates of the dilution/attenuation factors (DAFs) that would be needed during groundwater transport to reduce leachate lead levels to drinking water standards; and a summary of information **on** the likelihood that such DAFs are in fact achieved around landfills.

The chapter's second section examines the effectiveness of MSW landfills as long term sinks for lead in consumer products. This analysis projects the proportion of the lead remaining in the landfill at various times in both the near and distant future, based on known information about lead leaching rates from municipal landfills.

¹See NUS Corporation. Summary of Data on Municipal Solid Waste Landfill Leachate Characteristics, prepared for the U.S. Environmental Protection Agency, 1988.

²This chapter focuses only **on** the disposal of unprocessed municipal solid waste. Disposal of incinerator ash is considered separately in Chapter 4.

GROUNDWATER EXPOSURES AROUND MSW LANDFILLS

A review of groundwater lead levels should play an important role in the debate over the human health impacts of lead in municipal solid waste because these data provide the most direct indication of the likelihood that anyone will be exposed to drinking water with lead levels above EPA's action level. There are **two** possible approaches for evaluating the impact of potential lead releases from municipal landfills to groundwater. The first is to review monitoring data on lead concentrations in drinking water wells located around solid waste landfills. The second approach is to simulate groundwater lead concentrations based on the landfill leaching rate for lead and the hydrogeologic characteristics of municipal landfill sites.

At this point in time, neither of these approaches provides a definitive picture of groundwater lead concentrations. Long-term groundwater monitoring results for lead are not readily available for a large number of facilities. At the same time, modeling techniques for estimating groundwater quality are subject to a variety of uncertainties. Considering information from both approaches, however, does provide useful insights into the likelihood that lead concentrations at drinking water wells could exceed the lead action level. In the remainder of this section, we review the evidence from both *monitoring* and modeling studies. The modeling discussion is placed first since it provides a general overview of the factors that affect lead levels in groundwater.

Groundwater Modeling Data

A 1988 study prepared by NUS Corporation for EPA provides the most complete summary of available data on lead concentrations in leachate from municipal landfills.¹ This study reviewed the results of leachate testing at 83 MSW landfills located throughout the U.S. Information on lead was available for 139 leachate samples collected at **45** of these landfills (Exhibit 3-1).

A review of leachate data reported by NUS suggests that none of the samples had lead concentrations that would result in their designation as hazardous wastes under the requirements of the RCRA Toxicity Characteristic regulation. In fact, as shown in Exhibit **3-2**, over **25** percent of the samples are below the drinking water action level (0.015 mg/l) without any dilution or attenuation.²

¹NUS Corporation, Summary of Data on Municipal Solid Waste Landfill Leachate Characteristics, prepared for the U.S. Environmental Protection Agency, 1988.

²Dilution occurs as the leachate is dispersed into a larger volume of groundwater. Attenuation is a measure of the extent to which the lead is retained in the subsurface soil either through precipitation or through adsorption onto soil particles.

Exhibit 3-1

MUNICIPAL SOLID WASTE LANDFILL LEACHATE			
PRE-		10	
Sample	Lead Concentration (mg/l)	Sample	Lead Concentration (mg/l)
1	0.009	47	<0.05
2	0.015	48	<0.05
3	0.006	49	0.05
4	ND	50	0.05
5	ND	51	0.148
6	ND	52	<0.05
7	0.069	53	<0.05
8	0.29	54	<0.05
9	1.11	55	<0.01
10	ND	56	0.012
11	0.25	57	<0.01
12	0.07	58	<0.01
13	0.053	59	0.005
14	0.035	60	<0.05
15	0.061	61	0.059
16	0.012	62	<0.05
17	0.015	63	<0.05
18	<0.01	64	0.12
19	0.038	65	<0.05
20	0.031	66	<0.05
21	0.13	67	0.072
22	0.21	68	<0.05
23	0.18	69	<0.05
24	0.1	70	<0.05
25	<0.05	71	0.26
26	0.012	72	<0.05
27	<0.025	73	0.05
28	0.42	74	<0.05
29	<0.1	75	<0.05
30	<0.05	76	0.21
31	<0.05	77	0.46
32	<0.05	78	ND
33	<0.25	79	0.1
34	<0.05	80	ND
35	<0.05	81	0.3
36	0.29	82	0.015
37	<0.05	83	0.03
38	<0.05	84	ND
39	<0.05	85	1.23
40	<0.05	86	0.162
41	<0.05	87	0.055
42	<0.05	88	0.075
43	<0.05	89	<0.005
44	1.6	90	0.03
45	<0.05	91	0.039
46	0.085	92	0.13

Exhibit 3-1
(continued)

MUNICIPAL SOLID WAST		LANDFILL LEACHATE	
POST-1980		UNKNOWN AGE	
Sample	Lead Concentration (mg/l)	Sample	Lead Concentration (mg/l)
93	ND	115	0.14
94	0.048	116	<0.005
95	0.012	117	0.37
96	ND	118	<0.001
97	<0.05	119	0.018
98	<0.05	120	0.01
99	<0.05	121	0.022
100	<0.05	122	0.04
101	<0.05	123	0.026
102	<0.05	124	0.027
103	<0.05	125	0.018
104	0.07	126	<0.01
105	0.007	127	0.08
106	<0.01	128	0.3
107	0.079	129	0.06
108	<0.01	130	0.132
109	<0.03	131	0.065
110	0.024	132	0.01
111	<0.01	133	<0.005
112	<0.03	134	0.16
113	0.15	135	0.12
114	0.045	136	0.01
		137	0.03
		138	1.05
		139	0.05
Summary Statistics			
Facility Start-up Date	Maximum concentration (mg/l)	Minimum Concentration (mg/l)	Median Concentration' (mg/l)
Pre-1980	1.6	ND	0.05
Post-1980	0.15	ND	0.048
Unknown	1.05	ND	0.03
Total	1.6	ND	0.05

ND = No lead detected. The test detection levels were not given for these samples.

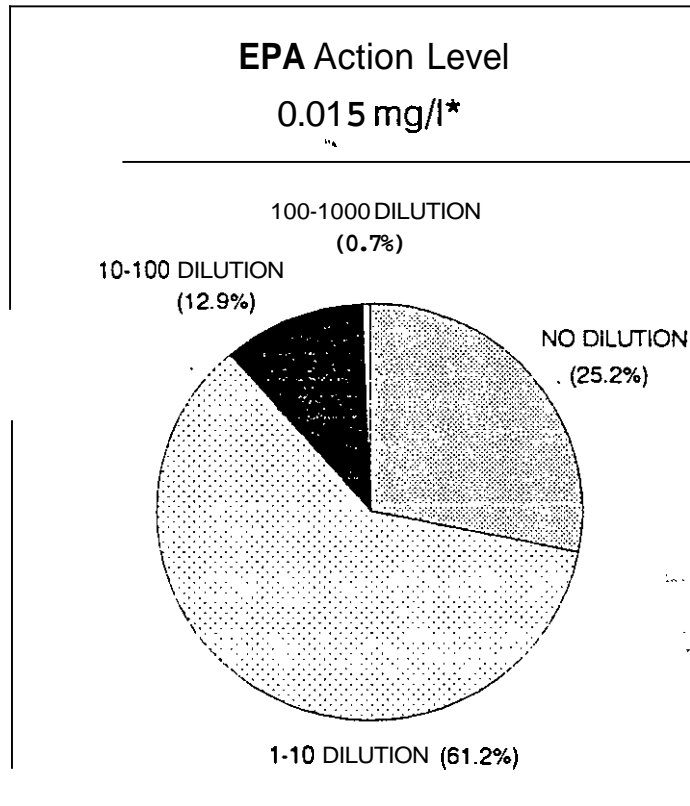
< = No lead detected. The test detection level is the listed concentration.

* Samples marked "ND" were excluded from the median calculation. For samples marked "<", test detection levels were used. The median values would almost certainly be lower if the actual concentrations of these "<" samples were known.

Source: NUS Corporation, "Summary of Data on Municipal Solid Waste Landfill Leachate Characteristics", prepared for U.S. EPA, July 1988.

Exhibit 3-2

REQUIRED DAFs FOR LANDFILL LEACHATE



- * Based on 139 samples. Undetectable concentrations with detection limits less than 0.015 ppm were assumed not to need any dilution. Undetectable concentrations with detection limits greater than 0.015 ppm but less than 0.15 ppm were assumed to require a dilution factor of 1-10. Undetectable concentrations with detection limits greater than 0.15 ppm but less than 1.5 ppm were assumed to require a dilution factor of 10-100. Undetectable concentrations with detection limits greater than 1.5 ppm but less than 15 ppm were assumed to require a dilution factor of 100-1000. Undetectable concentrations with no detection limits were assumed to require no dilution.

Source: Ec analysis of data in 'Summary of Data on Municipal Solid Waste Landfill Leachate Characteristics,' prepared for U.S. EPA by NUS Corporation, July 1988.

The remaining samples would require some additional dilution or attenuation-to achieve the lead drinking water standard. Most of these (61 percent of the 139 samples) require **less** than a 10-fold reduction in concentration between the landfill and a nearby well. Roughly 13percent need between a 10- and 100-fold reduction in concentration, and **less** than one percent (one sample) require slightly more than a 100-fold reduction.^{5,6}

Overall, the leachate analysis indicates that if DAFs of 100 are achieved for lead during the subsurface transport of leachate, then the 15 ug/l action level would be met at nearby wells. EPA is currently investigating the lead DAFs that are typically achieved around municipal landfills. Researchers at the Agency's Athens Environmental Research Laboratory have developed an approach for modeling the attenuation of lead, and this approach is being incorporated into EPA's Monte Carlo model for estimating required DAFs (EPACML).⁷ These researchers pointed out that lead is very strongly adsorbed onto soil particles and as a result is not readily transported except in low pH groundwater systems. Given this behavior, one of EPA's model developers suggested that his analysis indicates the 100-fold DAF for lead currently used in the Toxicity Characteristic regulation is unlikely to be reduced and could even be increased! This assertion was based on the results of model runs which found that a DAF of 100 is likely to be achieved at most sites even in the absence of attenuation of lead?

One EPA researcher also hypothesized that even higher DAFs might be justified if the concentration of lead in MSW leachate is low relative to the leachate concentrations assumed in the model scenarios resulting in the lowest DAFs. He indicated further research would be needed to test this hypothesis.

⁵According to EPA's Air Quality Criteria Document for Lead (June 1986), background concentrations of natural lead in groundwater are approximately 3 ug/l (page 1-38). Inclusion of this small background level does not dramatically alter the percentage of samples requiring different levels of dilution, and therefore, to simplify the calculations presented here, the estimates of required DAFs do not take background lead into consideration.

⁶Even these estimates of required DAFs may be conservative because the majority of the samples requiring higher DAFs are from pre-1980 landfills. Increased regulation since 1980 has reduced the disposal of industrial hazardous wastes in municipal landfills. Consideration of the 25 samples from landfills opened after 1980 suggests that **only** a ten-fold dilution/attenuation factor is required to bring all samples to the current drinking water standard (Exhibit 3-1).

⁷Personal communications with staff at the EPA Athens Environmental Research Laboratory, September 13, 1990.

⁸Personal communication with staff at the EPA Athens Environmental Research Laboratory, September 13, 1990. The DAF of 100 currently implied in the RCRA Toxicity Characteristic regulations for lead and seven other metals was not based on modeling results. EPA selected the DAF of 100 while admitting that little empirical data existed at that time to support it.

⁹There has been some concern that the presence of organics in MSW leachate could increase the mobility of lead. However, discussions with EPA staff suggest this effect is likely to become much **less** significant as leachate is diluted and dispersed in groundwater. Personal communication with staff at the EPA Athens Environmental Research Laboratory, October 1989.

In summary, initial discussion with EPA researchers indicates that the DAFs needed to reduce even the highest leachate lead concentrations to below the drinking water action level are likely to be achieved around most municipal landfills. This is true even though the NUS leachate data on which the conclusion is premised includes many older landfills that may have received hazardous as well as municipal solid wastes. Facilities that accept only municipal waste are even less likely to have releases that exceed the action level.

Groundwater Monitoring Data

In theory, groundwater monitoring should be a better source than modeling studies for information on the likelihood that concentrations of lead in drinking water will exceed the action level around municipal landfills. This is particularly true if the following two conditions are met:

1. Monitoring data are available from enough facilities to allow generalization of the range of possible lead concentrations.
2. Data have been collected over a long enough time period to provide a basis for determining whether levels of lead in groundwater change over time.

Unfortunately, at this point in time, summary data on groundwater lead concentrations fail to meet these two criteria. Although many states now require groundwater monitoring around MSW landfills, these data have been systematically collected in only a few states, none of which have implemented any data analyses." Furthermore, given the slow movement of groundwater in many locations, we do not know if the limited information already collected is representative of the long-term lead concentrations that might appear at monitoring or drinking water wells.

Despite these limitations, however, a review of the monitoring evidence accumulated to date is useful, particularly as a way of checking to see whether the conclusions of the groundwater modelers discussed above are contradicted by actual experience in any states. If such monitoring data were found, then greater skepticism about the modeling approaches might be justified.

In the remainder of this section we discuss three types of groundwater monitoring information that provide useful insights into the potential for lead in MSW to cause drinking water exposures above the action level. First, through a review of published information on known or suspected lead contamination incidents at landfills, we assess whether disposal of municipal solid waste has ever resulted in documented cases of elevated drinking water lead concentrations. Second, we examine a number of state databases containing information on monitored lead concentrations around MSW landfills. Finally, we discuss the results of conversations with a number of state regulators on their perceptions of the risks posed by lead around MSW landfills.

¹⁰Personal communication with Edward Repa, National Solid Waste Management Association, September 3, 1990.

Incidents of Lead Contamination at MSW Landfills

1988 NUS Corporation prepared a report for EPA summarizing case studies of 146 municipal landfills with known or suspected contamination." For each of the 146 landfills, NUS identified the principal contaminants of concern. Lead was explicitly mentioned at only 11 of the facilities. We conducted a more detailed review of these 11 landfills to determine the extent to which the lead contamination could be directly linked to MSW disposal.

The major conclusion of this investigation is that at none of these eleven sites is there any evidence that disposal of MSW resulted in off-site groundwater concentrations above the lead action level. Of the eleven sites, only two are even suspected of causing significant off-site lead contamination (Exhibit 3-3), and both of these are reported to have received large quantities of lead-bearing industrial waste.

At four of the eleven landfills, lead was detected in on-site groundwater but at relatively low levels. In the worst case, these on-site lead concentrations were only three times the current lead action level. The groundwater modeling research discussed earlier suggests that these concentrations would almost certainly be reduced to below the action level by dilution and attenuation processes occurring during groundwater transport. The fact that no off-site lead contamination of groundwater has been reported at these four sites lends support to this hypothesis.

At the three of the eleven landfills, state regulators reported that lead was mistakenly identified as a problem by NUS. At the remaining two sites, further site investigations have failed to confirm the presence of elevated lead concentrations in groundwater."

Overall, the investigation of known or suspected lead contamination incidents at MSW landfills points to no positive evidence that disposal of lead-bearing MSW has ever caused lead concentrations to exceed the action level in off-site groundwater. The only cases where significant off-site contamination is suspected or confirmed were at landfills that received lead-bearing industrial waste.

Additional State Groundwater Data

Additional contacts with state environmental regulators confirm that lead contamination of groundwater is not a problem around existing MSW landfills that have not received hazardous industrial wastes. We have identified five states that have assembled groundwater databases with relevant data. These typically include information about lead concentrations measured in on-site groundwater monitoring wells. In one case (Wisconsin) off-site lead concentration data for private drinking water wells are also provided. The databases usually group MSW landfills that have

¹NUS Corporation, Case Studies on Groundwater and Surface Water Contamination from Municipal Solid Waste Landfills, prepared for the U.S. Environmental Protection Agency, 1988.

¹²At one site, later results found contradictory evidence of groundwater contamination; at the other on-site groundwater investigations have not been completed.

LANDFILL INFORMATION COLLECTED FROM CASE STUDIES AND INTERVIEWS WITH STATE OFFICIALS

Landfill	Current Status	Potential Sources of Pb Onsite	Maximum Concentration of Pb Onsite	Environmental Conditions at Landfill	Comments
LANDFILLS WITH POTENTIALLY HIGH LEAD CONCENTRATION					
1. Johnstown Landfill New York	Closed since July 1989	Numerous textile mills in the area that disposed of lead-bearing dyes in landfills.	>0.05 ppm of Pb in onsite groundwater.	Site located in old gravel mining site -- after removing gravel operator deposited waste. Highly permeable sand and glacial moraines under site. Underground springs located down gradient from the site and form the headwaters of a creek.	RI/FS actively underway. No data publicly available at this time. There is no definitive evidence that landfill contaminated domestic wells. There have been complaints by area residents of poor water quality. Ten years ago NY Health Department recommended that city close a public well near site but never proved that landfill contaminated well. One homeowner located upgradient of landfill had well that tested positive for 25 priority pollutants, city settled with him even though it was never established that landfill caused contamination. Neighbors' wells showed no contamination. State official believes similar contamination could not occur now because NY has strict landfill design requirements -- double composite liners required with leachate collection system.

Exhibit 3-3

LANDFILL INFORMATION COLLECTED FROM CASE STUDIES AND INTERVIEWS WITH STATE OFFICIALS
(continued)

Landfill	Current Status	Potential Sources of Pb Onsite	Maximum Concentration of Pb Onsite	Environmental Conditions at Landfill	Comments
LANDFILLS WITH POTENTIALLY HIGH LEAD CONCENTRATION					
2. Oswald Landfill Pennsylvania	Superfund NPL Site.	Industrial sludge including battery casings dumped at site.	12 ppm of Pb in onsite groundwater; and 0.6 ppm in offsite groundwater.	Groundwater flow high in the area.	Prior to 1952 operated as an open iron mine pit; 1952-1970 operated as an open dump; 1970-1978 operated as an unlined municipal waste site.
LANDFILLS WITH ONSITE LEAD CONCENTRATIONS SIMILAR TO MUNICIPAL SOLID WASTE LEACHATE					
3. Victoria City Landfill Texas	Active	Municipal waste, sewage sludge, and construction debris.	0.16 ppm of Pb in onsite groundwater.	N/A	State official not willing to provide information.

Exhibit 3-3

ADDITIONAL INFORMATION COLLECTED FROM CASE STUDIES AND INTERVIEWS WITH STATE OFFICIALS
(continued)

Landfill	Current Status	Potential Sources of Pb Onsite	Maximum Concentration of Pb Onsite	Environmental Conditions at Landfill	
LANDFILLS WITH ONSITE LEAD CONCENTRATIONS SIMILAR TO MUNICIPAL SOLID WASTE LEACHATE					
4. Benton Sanitary Landfill Arkansas	Opened in 1981 and plans to close in 1990.	Industrial and aluminum processing wastes.	0.09 ppm of Pb in onsite groundwater.	Landfill located in abandoned bauxite mines; floor of mines composed of clay which according to city official provide natural liner.	State official stated that the landfill is well run and compliance with its permits; they are not aware of groundwater contamination. City official stated that during the past few years groundwater contamination has not occurred at the active site.
5. Pickettville Road Landfill Florida	Superfund NPL site.	Lead acid batteries, and waste oil deposited onsite.	Lead levels in on-site groundwater reported as "low".	Rural area with creek cutting across property. Land surface several feet above sea level.	RI/FS in progress. State official believes likelihood of similar situation arising in future is reduced because state now requires liners and leachate collection systems.

Exhibit 3-3

LANDFILL INFORMATION COLLECTED FROM CASE STUDIES AND INTERVIEWS WITH STATE OFFICIALS
(continued)

Landfill	Current Status	Potential Sources of Pb Onsite	Maximum Concentration of Pb Onsite	Environmental Conditions at Landfill	Comments
LANDFILLS WITH ONSITE LEAD CONCENTRATIONS SIMILAR TO MUNICIPAL SOLID WASTE LEACHATE					
6. Pearsall Road Landfill Texas	Closed.	Miscellaneous industrial wastes.	<0.05 ppm Pb in onsite groundwater.	Landfill built in drainage pathway and on alluvial clay deposits; located near a creek.	Site located in industrial area near an airforce base; state officials have not been able to pinpoint source of contamination; groundwater up- gradient of landfill more contaminated than groundwater down-gradient and state official thinks landfill leachate may dilute concentration of contaminants. State official said aquifer would never be used for drinking water because the water circulates in clay deposits.

LANDFILL INFORMATION COLLECTED FROM CASE STUDIES AND INTERVIEWS WITH STATE OFFICIALS
(continued)

Landfill	Current Status	Potential Sources of Pb Onsite	Maximum Concentration of Pb Onsite	Environmental Conditions at Landfill	Comments
LANDFILLS WITH INCOMPLETE DATA					
7. Stark County/ Breitenstine Landfill Ohio	Active	Industrial wastes.	N/A	Located in an abandoned strip mine; natural clay liner.	The landfill is currently doing a hydrological assessment of the site and installing new wells. They are also examining old wells to determine if they can use them. Preliminary sampling of old wells show contradictory results -- one set of samples indicated contamination of groundwater at the site, but another set of samples showed no contamination. Most residents in area rely on groundwater for drinking water. No private wells have reported monitoring results to the state.
8. South Charleston Municipal Landfill West Virginia	Closed.	Chemical wastes disposed.	N/A	N/A	Landfill applied to state for approval of closure two years ago. State is requiring the installation of wells as part of closure requirements. No analysis of leachate data available.

N/A = Not Available.

LANDFILL INFORMATION COLLECTED FROM CASE STUDIES AND INTERVIEWS WITH STATE OFFICIALS
(continued)

Landfill	Current Status	Potential Sources of Pb Onsite	Maximum Concentration of Pb Onsite	Environmental Conditions at Landfill	Comments
LANDFILLS WITH NO LEAD OR CADMIUM PROBLEMS					
9. Eastside Colby Landfill Oklahoma	Closed.	N/A	N/A	N/A	Contamination had been reported at the site, but later resampling and analysis found that errors were made in sampling and lab analysis. Concentration of Pb was verified to be below MCL. The name of the landfill is Ponca City Municipal Landfill and not Eastside Colby.
10. Jackson East Sanitary Landfill Florida	Closed.	No significant industry in the area.	N/A	N/A	State officials claim that there is no lead contamination at landfill. The site is under investigation for suspected organics contamination. Site had a valid permit and conformed to state
11. Bedford County Landfill Shelbyville, Tennessee	Active.	N/A	N/A	N/A	Landfill is still active and operated by a private firm. State official said that groundwater samples taken at site during the past 3 years have shown no lead contamination, although some earlier sampling did report on-site Pb above the MCL.

SOURCES OF INFORMATION

Landfill	Contact
1. Johnstown Landfill (New York)	New York Bureau Municipal Waste Permitting
	New York Region 5 Solid Waste Office
	New York Department of Environmental Conservation, Division of Hazardous Waste Remediation
2. Oswald Landfill (Pennsylvania)	Pennsylvania Department of Natural Resources
	EPA Region 3 Superfund Program
3. Victoria City Landfill (Texas)	Texas Health Department
	Texas Health Department
4. Benton Sanitary Landfill (Arkansas)	Arkansas Department of Pollution Control & Ecology
	Oversees Landfill operation for the City of Benton
5. Pickettville Road Landfill (Florida)	Florida Department of Environmental Resources
	Northeast Department of Environmental Resources District
6. Pearsall Road Landfill (Texas)	Texas Health Department
	Texas Health Department
7. Stark County/Breitenstine Landfill (Ohio)	Ohio Environmental Protection Agency
8. South Charleston Municipal Landfill (West Virginia)	West Virginia Bureau of Solid Waste Management
9. Eastside Colby Landfill (Oklahoma)	Oklahoma Solid Waste Division
10. Jackson East Sanitary Landfill (Florida)	Florida Department of Environmental Resources
	Northwest Department of Environmental Resources District
11. Bedford County Landfill (Shelbyville, Tennessee)	Tennessee Department of Health and Environment, Division of Management

received hazardous waste in the past with those that may have received only municipal solid waste, making it impossible to analyze only MSW-receiving facilities. As a result, the estimates probably represent an upper bound on the groundwater concentrations that would be observed around facilities that did not dispose of hazardous industrial wastes. Even given this tendency of the data to overstate concentrations, our analysis of these databases suggests that the risk of exposure to contaminated groundwater around MSW landfills is limited.

Wisconsin

Based on our investigations, the most comprehensive available groundwater monitoring database is maintained by the Wisconsin Department of Natural Resources. This database not only provides 6,086 groundwater samples from on-site monitoring wells at 101 municipal solid waste landfills, but also includes lead sampling at a number of private wells. We analyzed the on-site groundwater data using a DAF-based approach similar to the one used for the landfill leachate data. In this case the DAF is a measure of the extent to which groundwater concentrations would have to be reduced during transport from on-site monitoring locations to off-site drinking water wells.

Exhibit 3-4 shows the distribution of the required DAFs for all 6,086 on-site groundwater samples." As shown, the majority of the Wisconsin on-site monitoring well samples (approximately 71 percent) would require no dilution to meet the current drinking water standard. Another 24 percent would require less than a 10-fold reduction in concentration during off-site transport, while four percent would require a DAF of between 10 and 100. An insignificant fraction of the samples (roughly 0.6 percent) would require more than a 100-fold reduction in concentrations during off-site transport.¹⁴

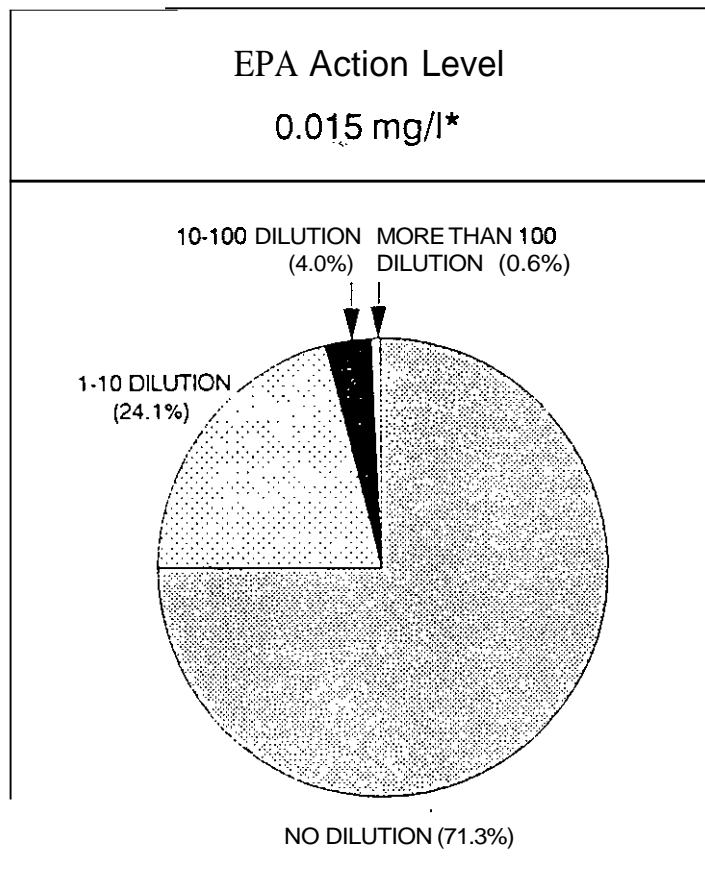
After facilities that disposed industrial hazardous waste were removed from the database, off-site monitoring results from private drinking water wells suggest that adequate dilution/attenuation is achieved around Wisconsin MSW landfills, although this was not immediately apparent from an analysis of the raw data. The preliminary analysis of lead concentrations in 1,867 samples of water from homes with private wells located near landfills indicated that approximately 19 percent exceeded EPAs drinking water action level. Because of the relatively large number of drinking water exceedences, we conducted a more thorough examination of the data.

"Over 75 percent of the samples showed lead concentrations below detection limits. This analysis assumed these concentrations were equal to the detection limit of the test. This is a conservative assumption, particularly given the fact that many of the detection limits on the older samples are above current drinking water standards.

¹⁴State officials indicated that higher recorded lead concentrations may be attributable to misclassification of leachate data (personal communication with Tim Sagal, Wisconsin DNR, March 5, 1991). As discussed further below, the acceptance of industrial waste may also partially explain higher observed concentrations.

Exhibit 3-4

REQUIRED DAFs FOR ON-SITE GROUNDWATER AT WISCONSIN LANDFILLS



- Based on 6,086 samples. Undetectable concentrations with detection limits less than the MCL were assumed to require no dilution. Undetectable concentrations with detection limits between 1 and 10 times the MCL were assumed to require a dilution factor of 1-10. Undetectable concentrations with detection limits between 10 and 100 times the MCL were assumed to require a dilution factor of 10-100. Undetectable concentrations with detection limits greater than 100 times the MCL were assumed to require more than 100-fold dilution.

Source: IEC analysis of groundwater sampling results from Wisconsin landfills

This investigation revealed the strong possibility that the majority of these elevated drinking water samples might be attributable to disposal of industrial hazardous wastes. Our review indicated that **sixty** percent of the private well samples showing exceedences of the action level (190 of 319) occurred at only three facilities, **all** operated by Waste Management of Wisconsin, Inc. Through contacts with the firm we learned that **two** of the facilities are currently listed as Superfund sites (Brookfield and Muskego) and the third is a former RCRA hazardous waste facility (Omega Hills). Company representatives noted that all three facilities accepted large amounts of industrial waste in the past, and therefore do not represent typical municipal solid waste landfills. Furthermore, they pointed out that private well samples are typically taken from taps in homes and that **as** a result, lead pipes or plumbing solder could be partially responsible for the higher concentrations observed."

Although we did not contact every landfill with private drinking water samples exceeding the drinking water standard, our discussions with Waste Management of Wisconsin, Inc. suggest that elevated concentrations of lead in private wells are frequently attributable to the disposal of industrial hazardous wastes. Furthermore, since sampling typically occurs at the drinking water tap, the results do not control for the possibility that elevated lead is caused by lead plumbing in the sampled homes. Past studies for EPA indicate that even in the absence of waste landfills, more than 16 percent of partly flushed kitchen tap samples could exceed 0.02 mg/l of lead." After removal of those samples that may be affected by hazardous waste disposal, only seven percent of the Wisconsin drinking water samples exceed the 0.015 mg/l action level, well below what would be expected due to lead plumbing alone.

In light of these facts, we conclude there is **no** evidence that adequate dilution or attenuation of lead is not achieved around the Wisconsin landfills that did not dispose of industrial hazardous wastes. This conclusion is echoed in a recent decision by the Wisconsin Solid Waste Division to discontinue required groundwater monitoring for lead."

"Personal communication with Mike Prattke of Waste Management of Wisconsin, March 21, 1991.

"Reducing Lead in Drinking Water: **A** Benefit Analysis," **U.S.** Environmental Protection Agency, December 1986, page 6.

"Jack Connelly of the Wisconsin Solid Waste Division stated that Wisconsin has recently discontinued metals monitoring at MSWLFs because of the consistently low concentrations detected. While new Subtitle **D** rules may require metals monitoring, Wisconsin intends to oppose such regulations.. Personal Communication, March 1, 1991.

Pennsylvania

Pennsylvania maintains a database that includes groundwater monitoring data from approximately 112 municipal landfills, 38 of which showed detectable concentrations of lead in on-site groundwater monitoring wells. Of the 433 groundwater samples available at the 38 facilities with detectable lead, over 55 percent had concentrations below the current drinking water action level. Most of the remaining samples (42 percent) had concentrations that would require ten-fold dilution and attenuation; the remaining three percent would require between 10- and 100-fold reduction.

Pennsylvania officials indicate that additional dilution and attenuation is likely to occur at facilities with monitoring well samples above the action level, making it improbable that off-site drinking water wells will have lead concentrations as high as the on-site values observed in the data base. In addition, they noted that some of the samples requiring significant dilution are likely to be undiluted leachate rather than groundwater. In these cases one would expect further dilution to occur when the leachate mixes with the groundwater.”

New Jersey

New Jersey also maintains an extensive database on monitored contaminant concentrations in groundwater around waste management sites. The results of our analysis of these data are consistent with those for Wisconsin and Pennsylvania -- they show limited potential for off-site exposures to contaminated groundwater. Of the 19,440 New Jersey samples analyzed, over 60 percent were below the current drinking water action level and would therefore require no dilution. Of the remaining samples, over 35 percent would require a DAF of less than ten, and one percent would require a DAF between ten and 100. Again, a small number of samples (roughly 0.5 percent) would require a DAF greater than 100. This frequency distribution of concentrations should be thought of as an extreme upper bound on groundwater contamination at municipal landfills since the New Jersey data include information on municipal solid waste landfills as well as hazardous waste facilities.

Florida

Florida also has assembled a data base of monitored groundwater concentrations. Although information from many facilities have yet to be entered into the database, 628 samples from 15 landfills were available.” Of these samples, over 99 percent would require a DAF of less than ten; less than one percent would require a DAF between ten and 100.

“Personal communication with Jeff Hassen, Pennsylvania Department of Environmental Resources, Bureau of Waste Management. January 31, 1991. Pennsylvania officials point out that the groundwater data base is in its formative stages and advise caution in interpreting the data since limited quality control has been exercised to date.

¹⁹All these samples were taken in the last two years. Therefore, these data are likely to be more representative of modern MSW landfill conditions.

Illinois

The Illinois data base is somewhat **less** useful than the others since it does not explicitly include information **on** concentrations around municipal landfills. Instead the data base provides lead concentrations in approximately 6,000 groundwater samples collected around the state. According to John Shafer, director of the Illinois Groundwater Quality Survey, lead levels are typically "well below" the drinking water action level, with a median concentration of .005 mg/l.²⁰ Although the Illinois data have never been sorted to identify samples from wells located near MSW landfills, Tom Holm, director of Illinois' Environmental Chemistry Division, was unaware of any incidents of elevated lead in drinking water wells located near municipal landfills that had not received industrial wastes."

Interviews with Regulators in Other States

In addition to the data collection and analysis effort described above, we interviewed solid waste and groundwater protection officials in 15 states and asked them to comment on the extent to which lead in MSW landfills poses a threat of drinking water contamination.' Regulators in the following states were contacted: New York, Minnesota, Kansas, Michigan, Colorado, Nebraska, Ohio, Washington, New Hampshire, Utah, Iowa, North Carolina, Missouri, Texas, and Georgia." Exhibit 3-5 contains a list of the persons contacted in these states. None of the officials reported any incidents in which drinking water wells were contaminated by lead leaching from nearby MSW landfills that had not received industrial hazardous wastes?' All the regulators interviewed confirmed the hypothesis that lead in MSW does not pose a significant threat to groundwater.

Conclusions on Groundwater Exposures Around MSW Landfills

The groundwater modeling and monitoring data discussed above should play a critical role in any decision **on** the need for further regulation of lead in municipal solid waste since groundwater is the primary **exposure** pathway for lead in landfills managing unprocessed MSW. Based on our review of available information, groundwater modeling work suggests that lead in leachate from

; et al, An Assessment of Groundwater Quality and Hazardous Substance Activities in Illinois with Data for a State-Wide Monitoring Strategy, Illinois Department of Natural Resources, 1985.

"Personal communication, September 1 1990.

²⁰It is to be noted that state groundwater levels were not to add to the risk of drinking water contamination with respect to a standard of 0.05 mg/l, the standard in effect at the time of the survey.

²¹Aside from an emphasis on populous states the selection of these states was largely random.

²²Illinois, Michigan and North Carolina stated that several wells have shown groundwater concentrations above the drinking water standard, but that this is likely to be attributable to the acceptance of industrial waste in the area; no mining activity is suspected.

Exhibit 3-5

SUMMARY OF STATE SURVEY ON
GROUNDWATER CONTAMINATION AROUND MSWLFs

State	Contact	Office
New York	Ron Entringer	Drinking Water Office
Minnesota	Scott Fox	Office of Solid Waste
Kansas	Chuck Linn	Solid Waste Management Section
Michigan	Brad Venman	Office of Solid Waste
Nebraska	Mark Fischer	Groundwater Section
Ohio	Grover Thompson	Groundwater Division
Washington	Guy Gregory	Groundwater Unit, Water Quality Program
Colorado	Paul Paulson	Solid Waste and Incident Management Section
Iowa	Paul Lundy	Solid Waste Protection Division
New Hampshire	Walter Carlson	Water Supply and Pollution Control Division
Missouri	Jim Matiejcic	Division of Environmental Quality, Enforcement Section
Georgia	Carole White	Solid Waste Division
North Carolina	Bobby Lufty	Solid Waste Division
Texas	AR. Smith	Hazardous and Solid Waste Bureau, Groundwater Protection Section
Utah	Ralph Bonn	Bureau of Solid and Hazardous Waste

landfills almost certainly is diluted or attenuated to below drinking water standards by the time it reaches drinking water wells located near MSW landfills. Available monitoring data provide additional support for this conclusion. Our review of these data found no evidence linking lead in MSW to known incidents of groundwater contamination around municipal landfills containing only municipal refuse.

MSW LANDFILLS AS LONG-TERM ENVIRONMENTAL SINKS FOR LEAD

In the debate over the need to reduce the quantity of lead introduced into commerce each year, concerns have been raised about the metal's long-term accumulation in the environment and the potential impact of such accumulations on public health. EPA concerns about the long-term fate of lead suggest a need to evaluate the extent to which municipal landfills permanently render lead unavailable for human exposures. In the discussion that follows, we review what available data say about the ability of landfills to function as long-term sinks for lead. If landfills are effective sinks, concerns about the need to reduce the amount of lead in consumer products that ultimately end up in MSW should be alleviated.

A critical factor in determining whether continued use of lead in consumer products will cause a long-term increase in exposures is the extent to which the lead stays in the landfill. If the lead remains buried and isolated, the potential for human exposure may differ little from that associated with natural lead ore bodies. Conversely, if the lead rapidly leaches from the facility, there may be a greater potential for exposure. Although empirical studies of lead retention in landfills are unavailable, simple calculations based on the lead content of MSW and leachate concentration data provide valuable insights into the long-term fate of lead.

To illustrate lead's fate, we have estimated for a typical landfill the number of years required to leach the MSW lead into the environment. This estimate is developed by dividing the total quantity of MSW lead placed in the landfill by the annual release rate of lead from the facility (Exhibit 3-6). In the example illustrated in Exhibit 3-7, we have assumed a landfill cell that is 100 meters square and 20 meters deep. Based on Franklin Associates' estimate that a cubic meter of landfilled garbage weighs 466 kilograms, we project that 93,000 tonnes of garbage would be placed in the ground over the life of the cell.²⁵ Using an average lead content of 319 ppm, we estimate that roughly 30 tonnes of lead are present upon closure of the cell.²⁶

²⁵Franklin Associates, 1990, page 88.

²⁶This average is based on the lead concentration data found in the analysis of MSW samples (Chapter 2).

Exhibit 3-6

MSWLF LEAD LEACHATE MODEL

METHODOLOGY									
1. CALCULATION OF THE AMOUNT OF LEAD IN A GIVEN MSWLF									
Total Lead		=	Landfill Volume	•	Garbage Density	•	Lead Fraction		
(tonnes)			(m ³)		in Landfill		in Garbage		
					(tonnes/m ³)				
2. CALCULATION OF THE LEAD LEACHATE RATE									
Lead Leachate Rate		=	Landfill Area	•	Precipitation Rate	•	Precipitation Infiltration	•	Lead Concentration in MSWLF Leachate
(tonnes/yr)			(m ²)		(m/yr)		(percent)		(tonnes/liter)
									Metric Conversion (liter/m ³)
3. CALCULATION OF THE YEARS REQUIRED FOR COMPLETE LEACHING OF LEAD FROM MSWLF									
Number of Years Required for Complete Leaching of Lead from MSWLF		=	Total Lead in MSWLF	/	Lead Leachate Rate				
			(tonnes)		(tonnes/yr)				

HSWLF LEAD LEACHATE MODEL

	Average Lead Concentration in MSWLF Leachate
Total Lead in MSWLF	29.7 tonnes
Lead Leachate Rate	0.18 kg/yr
Lead Completely Leached in:	165,257 yrs
Percent of Lead Leached per year	0.0006%
Assumptions	
Landfill Width	100 meters
Landfill Length	100 meters
Landfill Depth	20 meters
Garbage Density in Landfill 1	0.4662 tonnes/m ³
Lead Concentration in Garbage 2	319 ppm
Rate of Precipitation 3	1 m/yr
Precipitation Infiltration 4	0.3
Lead Conc. in MSWLF leachate 5	0.06 mg/l

Sources:

- (1) Franklin Associates, Ltd. "Characterization of Municipal Solid Waste in the United States: 1990 Update", 1990.
- (2) IEC sampling method. Estimate obtained by averaging the reported lead concentrations of 23 as-received MSW samples from 5 different studies.
- (3) Bureau of the Census, "Statistical Abstract of the United States: 1990".
- (4) Hjelmar, Ole. "Characterization of Leachate from Landfilled MSW Ash", in Proceedings to International Conference on Municipal Waste Combustion, Vol. 1, p.3B-3, 1989.
- (5) NUS Corporation. "Summary of Data on Municipal Solid Waste Landfill Leachate Characteristics", July 1988.

The annual leaching rate for lead is based on an estimate of the total quantity of leachate generated and the average lead content of leachate at MSW landfills. The leachate generation calculation assumes one meter of rainfall per year, a typical amount for the eastern U.S., and a 30 percent infiltration rate through the cover of the cell.²⁷ This results in the annual generation of three million liters of leachate. The average lead content of leachate is based on the arithmetic average of all leachate samples summarized in the NUS report on landfill leachate. Multiplying the quantity of leachate by the average concentration of lead results in the release of 0.2 kilograms of lead from the landfill each year, assuming a complete absence of operable liners and/or leachate collection systems.

The final step in the calculation, dividing the quantity of lead in the landfill by the annual release rate, indicates that most of the lead remains in the landfill for a very long time. Under the assumptions underlying this scenario, less than 1/1000th of one percent of the lead is leached each year. After 10,000 years of leaching, 95 percent of the lead will still be in the landfill.

Further restricting the availability of lead in the environment is the behavior of lead after its release to the subsurface. Because it is strongly attenuated in most hydrogeologic environments, much of the lead leached from a landfill could be expected to precipitate out of the groundwater or to be adsorbed onto subsurface soil particles. A DAF of 100, currently considered by EPA researchers to be a lower bound for lead, implies that 99 percent of the lead remains in the subsurface soil. This additional tendency of lead to remain in media to which people are unlikely to be exposed provides further assurance that the amount of lead available for human exposure over time is not increasing significantly as a result of municipal waste disposal.

In summary, landfills disposing of lead-bearing municipal waste are effective sinks for lead. Using leachate concentrations representative of existing landfills, less than 1/1000 of one percent of the lead disposed of is annually released from the landfill. Extrapolating this to the national level, less than one ton of lead would be released from landfills each year as a result of the disposal of 156 million tons of garbage, containing 145,000 tons of lead, and this assumes a complete failure of leachate collection and liner systems located at municipal landfills.

CONCLUSIONS

Based on existing data, MSW landfills appear to be effective at restricting environmental releases of lead that could cause adverse human exposures. Although lead is sometimes present in landfill leachate, dilution and attenuation processes that occur during groundwater transport are believed to provide adequate assurance that lead levels will not exceed drinking water action levels at nearby wells.

Groundwater monitoring data from around municipal landfills confirm this conclusion. We reviewed information on 146 reported contamination incidents at municipal landfills and found only two cases where lead threatened off-site drinking water. In both these cases large quantities of hazardous industrial wastes were co-disposed with MSW at the sites, and these industrial wastes are believed to be the source of the contamination problem. The finding that lead in MSW is not a

²⁷Hjelmar, O., "Characteristics of Leachate from Landfilled MSWI Ash," proceedings of the International Conference on Municipal Waste Combustion, Hollywood, Florida, April 1989, page 3B-8.

source of groundwater contamination is supported by state groundwater monitoring data bases as well as conversations with state solid waste and groundwater protection officials who were unaware of any lead contamination incidents caused solely by municipal waste disposal.

Finally, the long-term buildup of lead in the environment as a result of landfill disposal of municipal waste does not appear to be a problem. Analysis of lead release rates from landfills shows that releases to the environment occur very slowly. Thousands of years are needed to remove even a small fraction of the lead initially placed in a typical landfill cell.

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POTENTIAL EXPOSURES FROM INCINERATION OF LEAD-BEARING MUNICIPAL SOLID WASTE

CHAPTER 4

INTRODUCTION

According to recent estimates, approximately 16 percent of all MSW generated in the U.S. is burned in municipal waste combustors (MWCs), with this percentage expected to increase in the future.¹ Given the large volume of waste incinerated, the potential for lead exposures around MWC facilities is a consideration in evaluating the costs and benefits of reductions in the lead content of municipal waste. Whether or not the current lead content of MSW poses a significant risk of adverse exposures can be determined through an assessment of the potential releases of lead from the combustion process itself and from associated ash management. In this chapter we consider several potential categories of exposure. First, stack emissions have the potential to affect populations around MWCs both through direct inhalation as well as through post-deposition, indirect exposures such as ingestion of lead-contaminated soil, dust or food. Fugitive emissions, such as those experienced during ash handling and transport, can potentially result in workplace and off-site inhalation exposures. Finally, the potential leaching of lead from ash disposal facilities can result in groundwater contamination and subsequent drinking water exposure.

EXPOSURES DUE TO STACK EMISSIONS

In this section we assess the potential for populations located near M W G to be exposed to lead emissions. We consider both direct exposures (inhalation) as well as indirect exposures (post-deposition ingestion).

¹Franklin Associates, Ltd., 1990, page 74.

Direct Exposures Due to Stack Emissions

Modeling studies are currently the most complete source of information on the contribution of MWC stack emissions to ambient air concentrations of lead! In the 1987 Municipal Waste Combustion Study, EPA presented modeling data on exposures to lead at all existing M W O and around a **series** of model plants representing the air pollution controls anticipated at facilities being built in the late 1980s.³ EPA revised this study in 1989 using what it believes are better emission factors for incinerators and representative instead of actual incinerator locations (making the findings more generalizable).'

The original MWC study concluded that, at even the most poorly controlled existing plant, average ambient lead concentrations would not exceed 60 percent of the current 1.5 microgram per cubic meter ($\mu\text{g}/\text{m}^3$) National Ambient Air Quality Standard (NAAQS). The 1989 revised study predicted that the contribution of existing M W O to ambient lead concentrations would be even lower than the original estimates. For model plants representing 18 categories of existing incinerators, annual average lead concentrations never exceeded three percent of the NAAQS (Exhibit 4-1). For new plants, predicted lead concentrations were even lower, never exceeding one percent of the NAAQS (Exhibit 4-2).

The revised study also included a "worst case" analysis of potential lead exposures. EPA based this analysis on the emission and locational characteristics of four existing plants that have the potential to cause high levels of exposure.⁶ This worst case assessment found lead levels slightly higher than those predicted by the model plant analysis, but these concentrations were still less than live percent of the NAAQS (Exhibit 4-3).

²We identified only one monitoring study of a municipal waste combustor. In the results from this study of a combustor located in northern Virginia, researchers were unable to differentiate the MWC releases from background levels (personal communication David Sussman, Ogden Martin Systems, January 1991). EPA staff had no knowledge of any other available monitoring studies (personal communication with Dave McLamb, Ambient Standards Branch, September 18, 1990).

³Radian Corporation, Municipal Waste Combustion Study: Assessment of Health Risks Associated with Municipal Waste Combustion Processes, prepared for the U.S. Environmental Protection Agency, 1987.

⁴"Baseline Risk Analysis to Support Municipal Waste Combustor New Source Performance Standard and Emission Guideline Development," memorandum from Rayburn M. Morrison, Pollutant Assessment Branch, U.S. Environmental Protection Agency, November 22, 1989.

⁵Radian Corporation, pages 2-13.

⁶"Baseline Risk Analysis to Support Municipal Waste Combustor New Source Performance Standard and Emission Guideline Development," page 5.

Estimated Baseline Ambient Lead Concentrations Concentrations from Existing [111(b)] Municipal Waste Combustor Emissions (Model Plant Analyses)		
Model Plant	Ambient Lead Concentration (Annual Average) (ug/cubic meters)	Percent of NAAQS
Modular Excess Air'	.04	2.7%
Rocking Grate Refractory	.04	2.7%
Large Starved Air	.02	1.3%
Modular Excess Air	.02	1.3%
Small Starved Air	.02	1.3%
Small Massburn Waterwall'	.009	0.6%
Small Massburn Waterwall	.008	0.5%
Massburn Refractory	.005	0.3%
Rotary Waterwall	.003	0.2%
Large Massburn Waterwall.	.003	0.2%
Rotary Waterwall.	.003	0.2%
Traveling Grate Refractory	.002	0.1%
Rotary Kiln Refractory	.001	0.1%
Large RDF'	.001	0.1%
Small RDF	.001	0.1%
Small RDF'	.001	0.1%
Mid Size Massburn Waterwall	0.001	0.1%
Large RDF	.0005	0.03%

* Newly constructed

Source: Morrison, Rayburn M. "Baseline Risk Analysis to Support Municipal Waste Combustor New Source Performance Standard and Emission Guideline Development", U.S. EPA, Office of Air Quality, Pollutant Assessment Branch, Nov.22, 1989.

Exhibit 4-2

Estimated Baseline Ambient Lead Concentrations Concentrations from New [111(b)] Municipal Waste Combustor Emissions (Model Plant Analyses)		
Model Plant	Ambient Lead Concentration (Annual Average) ($\mu\text{g}/\text{m}^3$)	Percent of NAAQS
Modular Starved Air	.01	0.7%
Large Massburn Waterwall	.01	0.7%
Massburn Rotary Kiln	.01	0.7%
Fluidizing Bed (Bubbling Bed)	.009	0.6%
Small Massburn Waterwall	.0075	0.5%
Mid Size Massburn Waterwall	.007	0.5%
Modular Starved Air (No Heat Recovery)	.007	0.5%
RDF	.006	0.4%
Massburn Refractory	.005	0.3%
Modular Excess Air	.005	0.3%
RDF (Co-fired)	.003	0.2%
Fluidized Bed (Circulating Bed)	.003	0.2%

Source: Morrison, Rayburn M. "Baseline Risk Analysis to Support Municipal Waste Combustor New Source Performance Standard and Emission Guideline Development", U.S. EPA, Office of Air Quality, Pollutant Assessment Branch, Nov. 22, 1989.

Exhibit 4-3

Estimated Ambient Concentrations for Baseline Conditions for Lead Emissions from Municipal Waste Combustors		
Model Plant	Estimated Ambient Lead Concentration* (ug/m ³)	Percent of NAAQS
Large Massburn Refractory Louisville, KY	.07	4.7%
Small Modular Starved Air Auburn, ME	.009	0.6%
Large RDF Dade County, FL	.007	0.5%
Large Modular Starved Air Tuscaloosa, AL	.0004	0.03%

* Ambient standard for lead = 1.5 ug/cubic meter (3 month average).

Source: Morrison, Rayburn M. "Baseline Risk Analysis to Support Municipal Waste Combustor New Source Performance Standard and Emission Guideline Development", U.S. EPA. Office of Air Quality, Pollutant Assessment Branch, Nov. 22, 1989.

These estimates are conservative because they assume pollution controls in existence prior to implementation of the currently proposed performance standards for existing MWCs.' As a result, they represent an upper bound on the level of exposures to lead. According to EPA staff, actual exposure levels after implementation of the new standards should be lower, although the reduction from the baseline levels cannot be estimated without further information about the specific controls that will be installed by existing facilities?

The only other major sources of data on potential exposures around MWCs appear to be individual incinerator permit applications. A review of one such application, for an incinerator at New York's Brooklyn Navy Yard, suggests that modeled exposure levels for lead are comparable to those estimated in the 1989 EPA study discussed above? Extensive site-specific modeling of the Brooklyn MWC showed maximum average annual lead concentrations of 0.0121 ug/m³, representing less than one-percent of the NAAQS.¹⁰ The assessment assumed that scrubber and baghouse pollution controls were in place. These technologies are currently viewed as state-of-the-art approaches for reducing emissions, and as a result, new facilities are generally expected to include similar controls and have similar exposure levels, although time was not available for us to verify this through a review of other MWC permit applications."

Indirect Exposures Due to Stack Emissions

Both the 1987 MWC study and the Brooklyn Navy Yard application also reviewed the potential lead exposures resulting from indirect pathways. The MWC assessment posed a "worst case" scenario in which a family growing much of its own food is located at the maximum deposition point for the incinerator. Under this worst case, the MWC study results indicate that over a 30 year operating life, an incinerator controlled to meet the proposed performance standards for existing sources is unlikely to cause adverse exposures to lead via the indirect exposure pathways such as soil ingestion by children." Similar conclusions were reached in the Brooklyn Navy Yard study, where

⁹Federal Register, 54 FR 52209, December 20, 1989.

¹⁰Personal communication with David Cleverly, Standards and Air Strategies Division, U.S. EPA, September 18, 1990.

¹¹Signal Environmental Systems, Inc. "Applicants Post-Hearing Brief," In the Matter of the Application for Permits to Construct and Operate the Proposed Brooklyn Navy Yard Resource Recovery Facility, 1987.

¹²Signal Environmental Systems, Inc., page 16.

¹³Personal communication with David Cleverly and Air Strategies Division, October 2, 1990.

¹⁴Radian Corporation, 1987 pages 3-49; and personal communication with David Cleverly of EPA's Standards and Air Strategies Division. September 17, 1990.

soil ingestion at the maximum deposition point was predicted to add an insignificant quantity of lead to a child's blood (**0.26 ug Pb/dl**). If a **10 ug/dl** definition of lead toxicity is used, this worst case estimate constitutes less than three percent of the level of concern."

EXPOSURES DUE TO FUGITIVE EMISSIONS

Information on **exposures** to fugitive emissions around incinerators and ash management facilities is limited. We located only four studies addressing this issue -- two conducted by Ogden Martin Systems, Inc., one by Midwest Research Institute (MRI), and one by the Coalition on Resource Recovery and the Environment (CORRE). We also reviewed Occupational Safety and Health Administration (OSHA) data from inspections at waste management facilities.

The first Ogden study provided monitoring data comparing workplace with ambient lead levels **for** the firm's MWC in Hillsborough County, Florida." Workplace lead samples were collected at **two** locations in the plant -- near the ash conveyor and at the feed table. Ambient samples of outdoor lead levels were collected simultaneously for five sites in Hillsborough County. Over a **48** hour sampling period, workplace lead concentrations **were** between **0.149 ug/m³** and **0.183 ug/m³**. These workplace lead concentrations are **less** than **12** percent of the NAAQS and approximately one percent of the OSHA permissible exposure limit (PEL). Outdoor samples collected during the same period at the five sites around Hillsborough County showed concentrations ranging from **0.05 ug/m³** to **0.16 ug/m³**. Based on these results, the researchers concluded that fugitive emissions resulted in workplace lead concentrations that were indistinguishable from the background ambient lead levels in Hillsborough County."

The second Ogden study provided monitored estimates of fugitive emissions from ash handling at their MWC in Haverhill, Massachusetts." **The** study considered the generation of ash dust from facility conveyors, truck loading, truck travel to the ash monofill, dumping of ash, and cover and maintenance activities. Ogden sampled four locations and found lead concentrations ranging between **0.043 ug/m³** and **0.08 ug/m³**. **These** samples were all slightly higher than the upwind lead concentration but represent only three to five percent of the NAAQS."

"Signal Environmental Systems, Inc. page **40**.

¹⁴Hahn, J.L., H.P. Von Dem Fange, and G. Westerman. "A Comparison of Ambient and Workplace Dioxin Levels from Testing in and Around Modern Resource Recovery Facilities with Predicted Ground Level Concentrations of Dioxins from Stack Emission Testing with Corresponding Workplace Health Risks," Chemosphere, Volume 19, pp **629-36, 1989**.

"Hahn et al., page **630**.

¹⁶Hahn, J.L., G.T. Hunt, R.G. Rumba, and J. Wadsworth, "Fugitive Particulate Emissions Associates with MSW Ash Handling - Results of a Full-Scale Field Program," paper presented at 83rd Annual Meeting of the Air and Waste Management Association, **June 1990**.

"**These** samples were collected on a day with below average wind speeds. We do not know how air concentrations would change at higher wind speeds.

The MRI study, prepared for EPA's Office of Solid Waste, represents a more extensive assessment of the potential exposures associated with fugitive emissions from ash management." The analysis predicted inhalation exposures resulting from a variety of ash management processes performed at M W O and ash disposal sites (e.g., loading ash into trucks, hauling, etc.). Releases from these processes were modeled using EPA's AP-42 emissions factors and dispersion was estimated using the Industrial Source Complex Long-Term (ISCLT) model. MRI used probabilistic (Monte Carlo) sampling techniques to predict the distribution of air lead concentrations around existing MWCs. The Monte Carlo procedures incorporate actual facility data on a variety of variables such as ash generation, ash characteristics (e.g., metals concentrations, moisture content), ash handling practices, and physical facility characteristics (e.g., length of haul routes).

MRI characterized adverse **exposures to lead** as the percentage of model **runs** in which air concentrations exceeded a reference air concentration of 0.09 ug/m^3 (*see* discussion below). According to MRI, this percentage should be interpreted as the likelihood that the maximum exposed individual (MEI) will experience an "unreasonable" exposure.

As shown in Exhibit 4-4, adverse exposures at MWCs were estimated to be minimal, with a one percent probability that an MEI at the site boundary would be exposed beyond the reference concentration and a zero likelihood of adverse exposure for an individual living 100 meters from the site boundary. Potential exposures at disposal sites are slightly higher, but still relatively low. If dust suppression and other controls are in effect, the most likely scenario according to MRI, exposures are projected to exceed the reference level between **2 and 4 percent of the time**.¹⁹

Overall the MRI results show little likelihood of adverse exposures around MWCs or ash disposal facilities. This is true even though MRI adopted a number of „very conservative and questionable assumptions in their analysis. For example, their findings concerning "unreasonable" exposures obviously hinge on the 0.09 ug/m^3 reference air concentration chosen for lead -- a level that is only six percent of the current NAAQS for lead (1.5 ug/m^3). MRI's reasons for selecting such a low reference level are not discussed, although the choice appears to be based on a guidance document developed by Versar, Inc.²⁰ No other documentation is provided for selecting this level, and it does not appear to have any regulatory basis. Furthermore, no data are provided on the degree to which this reference air concentration was exceeded, making it difficult to gauge the actual level of exposure associated with the releases. However, based on the trends in the MRI results, it is unlikely that any of the predicted concentrations approach the NAAQS for lead.

¹⁸ Special Management Standards for Municipal Waste Combustion (MWC) Ash, Midwest Research Institute, prepared for U.S. EPA, Municipal Solid Waste Program, June, 1990.

¹⁹As modeled, fugitive emissions are largely attributable to vehicle traffic on facility haul routes. Therefore, emission controls include practices such as watering of ash, covering truck beds with tarps, and routing traffic to avoid traveling on exposed ash.

²⁰Versar, Inc., Guidance on Metals and Hydrogen Chloride Controls for Hazardous Waste Incinerators, prepared for U.S. EPA Office of Solid Waste, September, 1988.

Exhibit 4-4

SUMMARY OF RESULTS OF MRI FUGITIVE EMISSIONS STUDY		
COMBUSTER SITE MODEL		
Percentage of model realizations exceeding reference air concentration of 0.09 ug/cubic meter		
	<u>At Facility Perimeter</u>	<u>100m from Facility Perimeter</u>
	1.2%	0.0%
DISPOSAL SITE MODEL		
Percentage of model realizations exceeding reference air concentration of 0.09 ug/cubic meter		
	<u>At Facility Perimeter</u>	<u>100m from Facility Perimeter</u>
With Dust Control		
- 50% effectiveness	n.a.	3.8%
- 75% effectiveness	n.a.	2.0%

Source: Midwest Research Institute, "Special Management Standards for Municipal Waste Combustion (MWC) Ash". prepared for U.S. EPA, Municipal Solid Waste Program, June, 1990.

MRI's use of the AP-42 factors also tends to overstate the potential exposures around MWCs and ash disposal facilities. In general, they **use** factors **for** materials with a much lower moisture content than incinerator ash. **As** a result higher releases of lead to the air are predicted than would actually occur.

The CORRE study addressed the impact of fugitive emissions on soil concentrations around an ash disposal facility, an exposure pathway not addressed in either the Ogden or MRI studies." Based on a review of soil samples collected over a three year period at the Woodburn ash monofill, the authors of this report concluded that soils surrounding the ash monofill were not affected by fugitive releases of ash from operations at the facility.

While the Ogden, MRI, and CORRE studies indicate a low likelihood of elevated lead **levels** at MWCs, there are some very limited data from OSHA suggesting that this may not be the case at all MWCs. Specifically, OSHA inspections at **20** refuse handling facilities (SIC 4953) found that workers in certain jobs (primarily maintenance) can be exposed to air concentrations of lead above the permissible exposure limit (PEL) of 50 $\mu\text{g}/\text{m}^3$.

Under OSHA's regulations, a PEL may be met through the **use** of respirators, making the exposures at these facilities readily susceptible to control. Moreover, given the low air levels measured at the Ogden facilities and at a number of the facilities inspected by OSHA, it is clear that incinerators with good housekeeping and health and safety practices can protect their workers from elevated exposures to lead.

Overall, our review of the fugitive studies leads **us** to the conclusion that emissions of lead are unlikely to pose a significant threat of adverse health effects to people living near MWCs. The MRI modeling analysis clearly indicates that fugitive releases from incinerators and ash management facilities are unlikely to cause adverse exposures to lead for people living around MWC facilities. This result is especially convincing given the extremely conservative assumptions about emissions and health reference levels embodied in their analysis. Furthermore although the OSHA data point to potentially elevated workplace exposures at **some** incinerators, the Ogden monitoring studies illustrate that workplace air lead concentrations can be kept well below both the PEL and the NAAQS (background to five percent of the NAAQS). The CORRE monitoring work also suggests that fugitive emissions are not causing any long-term buildup of lead in the soil around ash management facilities.

²¹Municipal Waste Combustion: Ash and Leachate Characterization Monofill -Third Year Study, AWD Technologies, October, 1990.

ASH DISPOSAL GROUNDWATER EXPOSURES

Municipal waste combustion concentrates upwards of 98 percent of the waste stream lead in the fly and bottom ash.²² Typically the ash is either co-disposed in a landfill with unprocessed municipal waste or placed in an ash monofill. Exposures to lead in the ash could occur either as a result of fugitive air emissions caused by ash transport and handling (addressed above) or through leaching of lead to groundwater. This section reviews available data on the likelihood that ash disposal will contaminate underground drinking water supplies at levels violating EPA standards.

Our approach for evaluating this likelihood is identical to the one used in Chapter 3 for landfills disposing of unprocessed municipal solid waste. In this approach, we gather leachate concentration data from the published literature and compare lead concentrations with the drinking water action level (0.015 mg/l). Where leachate levels exceed the action level, we determine the level of dilution or attenuation needed reduce lead levels to below the action level. We then review information on the likelihood that this degree of dilution/attenuation is achieved around facilities disposing of incinerator ash.

For ash monofills, a total of 44 leachate samples were available from fourteen facilities (Exhibit 4-5). These data indicate that under the 0.015 mg/l action level, in excess of 43 percent of the leachate samples require no dilution. 34 percent require a DAF of less than 10, and 21 percent require a DAF of between 10 and 100. One sample requires a DAF of approximately 200 (Exhibit 4-6).

As discussed in Chapter 3, EPA researchers have noted that lead is highly immobile in most groundwater environments and that a DAF of 100 is likely to be achieved at a high percentage of the landfill sites in the U.S.²³ In light of this observation, our analysis of required DAFs for monofill leachates implies a very low likelihood that releases of lead-bearing leachate from ash monofills will cause lead to exceed the action level in downgradient drinking water wells.

²²Estimates based on Figure 5.3 in National Incinerator Testing and Evaluation Program: Environmental Characterization of Mass Burning Incinerator Technology at Quebec City, prepared for Environment Canada, June, 1988. Performance tests using a well-operating massburn incinerator (low excess air, reasonable radiation temperature, good primary/secondary air ratio, low CO concentration) with electrostatic precipitators show that of the initial concentration of lead in refuse (660 ppm), 97.7 percent entered the bottom and fly ash, 0.6 percent was released in stack emissions, and the remaining 1.7 percent was unaccounted for.

²³See Chapter 3, pages 3-6.

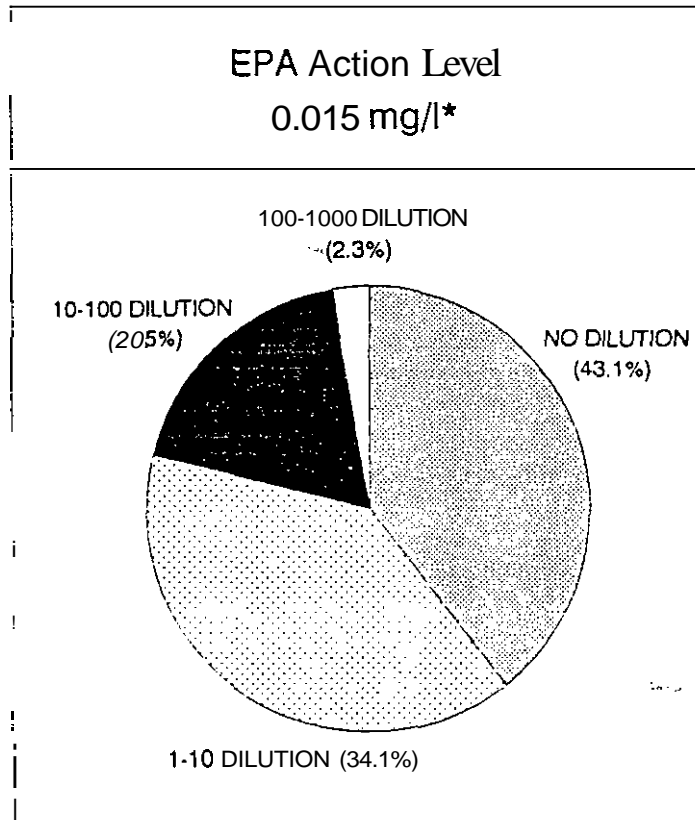
LEACHATE DATA ASH MONOFILLS				
Study Reviewed	Primary Source	Landfill Number	Sample	Lead Concentration (mg/l)
JS/EPA	Versar	1	1	0.206
			2	0.05
			3	0.05
		2	1	0.068
			2	2.92
			3	0.025
		3	1	0.925
			2	1.33
			3	0.214
JS/EPA	Literature Summary	1	1	1.16
		2	1	0.012
			2	0.25
			3	0.06
			4	0.033
IRSAR-IN	Versar-IN	1	1	0.19**
			2	0.19**
FF	RFF-Hjelmar*	1	1	0.005
			2	0.019
FF	RFF-M. Pirnie*	1	1	0.005
			2	0.71
FF	RFF-Marion County	1	1	0.011
			2	0.024
			3	0.025
ORRE/EPA	Corre	1	1	0.011
			2	0.024
			3	0.025
			4	0.054
			5	0.042
			6	0.018
			7	0.008
			8	0.01**
			9	0.01**
			10	0.01**
			11	0.01**
			12	0.01**
			13	0.01**
		2	1	ND***
		3	1	ND***
			2	0.034
		4	1	ND***
			2	ND***
			3	ND***
		5	1	ND***
			2	ND***

Note: • The values listed for these studies are maximum and minimum values.
Neither study listed the sample values inbetween the extreme values.
** No lead detected. The test detection limit for the sample is the listed concentration.
*** ND = No lead detected. The test detection limit for the sample was not given.
However, the tests used were selected so that the method detection limits were well below present levels of human, environmental, or regulatory concern" (Corre. p. ES-3). Levels as low as .008 were detected, and so it was assumed for this analysis that ND samples require no dilution.

Sources: (1) NUS/EPA. 1987. Characterization of MWC Ashes and Leachates from MSW Landfills, Monofills, and Co-Disposal Sites, Summary--Volume V of VII. EPA 530-SW-87-028E (GPO Washington, D.C.).
(2) Versar. Inc. Analysis of Ash Residue and Ash Monofill Leachate from the Indianapolis Resource Recovery Facility, for DPW Indianapolis. IN.
(3) Resources for the Future. Managing Ash from Municipal Waste Incinerators: A Report. Washington D.C., November, 1989.
(4) CORRE/EPA. Characterization of MWC Ash, Ash Extracts, and Leachates. 1990. EPA 530-SW-90-029A (GPO Washington, D.C.).

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Exhibit 4-6
REQUIRED DAFs
FOR ASH MONOFILL LEACHATE



* Based on 44 samples. Fifteen samples did not have detectable levels of lead. The seven samples without detection limits were assumed to require no dilution. The test for six of the fifteen samples had a detection limit of 0.01 mg/l; it was therefore assumed that they would require no dilution. The test for the remaining two samples had a detection limit of 0.19 mg/l; we made a worst case assumption that they would require a 10-100 dilution factor.

Sources: (1) NUS/EPA. "Characterization of MWC Ashes and Leachates from MSW Landfills, Monofills, and Co-Disposal Sites". *Summary--Vol. V, of VII.*

EPA 530-SW-87-028E (GPO Washington, D.C.). 1987

(2) Versar, Inc. "Analysis of Ash Residue and Ash Monofill Leachate from the Indianapolis Resource Recovery Facility", for DPW Indianapolis, IN.

(3) Resources for the Future. "Managing Ash from Municipal Waste Incinerators: A Report", Washington, D.C., November, 1989.

(4) CORRE/EPA. "Characterization of MWC Ash, Ash Extracts, and Leachates", EPA 530-SW-90-029A (GPO Washington, D.C.), 1990.

For facilities co-disposing incinerator ash with unprocessed municipal waste, information is much more limited than for the monofills. Currently we have leachate results from only four facilities (Exhibit 4-7). These data contain a maximum lead concentration higher than those for either the monofills or the landfills disposing unprocessed MSW. Given the small number of co-disposal landfills for which data are available, however, any conclusions about the relative lead levels at co-disposal facilities would be premature.

CONCLUSIONS

Overall, the data on the potential for exposures from incinerator stack emissions suggest that releases are unlikely to cause adverse exposures to lead via either direct or indirect pathways. According to EPA studies conducted to support development of new MWC performance standards, maximum ambient lead concentrations around MWCs will not exceed five percent (and are often less than one percent) of the current NAAQS even prior to implementation of the proposed new standards for existing incinerators. Air concentrations are anticipated to be even lower for new facilities. Data on indirect exposures also indicate that even under worst case conditions, contributions to blood lead are minor.

In the case of fugitive emissions, available monitoring data and modeling results also indicate a very low likelihood of adverse off-site human exposures. Monitored ambient air lead contributions from fugitive emissions around incinerators and ash handling facilities have been found to be only a fraction of the NAAQS, while modeling work designed to capture the full range of possible exposure conditions demonstrates the low probability that even an extremely protective ambient concentration would be exceeded. Workplace monitoring data also indicate that lead concentrations can be kept at levels that do not pose a threat to worker health. In addition, soil sampling at one ash monofill indicates that fugitive releases from ash disposal facilities are not contributing to a long-term buildup of lead in the soil.

Finally, disposal of incinerator ash in monofills appears unlikely to contaminate groundwater with lead levels above the drinking water standard. Although lead concentrations in leachate are sometimes above the drinking water action level, EPA modeling research suggests that dilution and attenuation in most cases will reduce lead to acceptable levels at nearby drinking water wells. Leachate data for co-disposal facilities are currently too sparse to make a reliable determination of groundwater exposure potential.

Exhibit 4-7
Summary of Actual Leachate Data
Codisposal Facilities

<u>Study Reviewed</u>	<u>Primary Source</u>	<u># Landfills</u>	<u># Samples</u>	<u>Lead Concentration</u>		
				<u>Minimum</u>	<u>Median +</u>	<u>Maximum</u>
NUS/EPA	NUS	2	6	0.01	0.02	0.027
RFF	Hjelmar	1		<0.001		0.49
RFF	Denison/Seigler	1	25			7.1

Sources: (1) NUS/EPA, 1987. Characterization of MWC Ashes and Leachates from MSW Landfills, Monofills, and Co-Disposal Sites, Summary -- Volume V of VII. EPA 530-SW-87-028E (GPO Washington, D.C.).

(2) RFF Study.